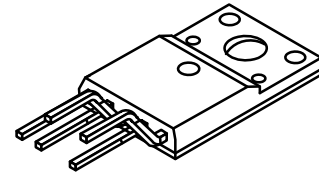


# Green Mode Fairchild Power Switch (FPS™)

## FSCQ Series

FSCQ0765RT / FSCQ0965RT /  
FSCQ1265RT / FSCQ1565RT



TO-220-5  
CASE 340BH

### Description

A Quasi-Resonant Converter (QRC) typically shows lower EMI and higher power conversion efficiency compared to a conventional hard-switched converter with a fixed switching frequency. Therefore, a QRC is well suited for noise-sensitive applications, such as color TV and audio. Each product in the FSCQ series contains an integrated Pulse Width Modulation (PWM) controller and a SENSEFET®. This series is specifically designed for quasi-resonant off-line Switch Mode Power Supplies (SMPS) with minimal external components. The PWM controller includes an integrated fixed frequency oscillator, under-voltage lockout, leading-edge blanking (LEB), optimized gate driver, internal soft-start, temperature-compensated precise current sources for loop compensation, and self-protection circuitry. Compared with a discrete MOSFET and PWM controller solution, the FSCQ series can reduce total cost, component count, size, and weight; while increasing efficiency, productivity, and system reliability. These devices provide a basic platform for cost-effective designs of quasi-resonant switching flyback converters.

### Features

- Optimized for Quasi-Resonant Converter (QRC)
- Advanced Burst-Mode Operation for under 1 W Standby Power Consumption
- Pulse-by-Pulse Current Limit
- Overload Protection (OLP) – Auto Restart
- Over-Voltage Protection (OVP) – Auto Restart
- Abnormal Over-Current Protection (AOCP) – Latch
- Internal Thermal Shutdown (TSD) – Latch
- Under-Voltage Lockout (UVLO) with Hysteresis
- Low Startup Current (Typical: 25  $\mu$ A)
- Internal High Voltage SENSEFET
- Built-in Soft-Start (20 ms)
- Extended Quasi-Resonant Switching
- This is a Pb-Free and Halid-Free Device

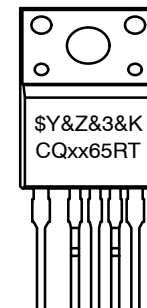
### Applications

- CTV
- Audio Amplifier

### Related Resources

- <https://www.onsemi.com/pub/Collateral/AN-4146.pdf>
- <https://www.onsemi.com/pub/Collateral/AN-4140.pdf>

### MARKING DIAGRAM



|          |                           |
|----------|---------------------------|
| \$Y      | = onsemi Logo             |
| &Z       | = Assembly Plant Code     |
| &3       | = Date Code (Year & Week) |
| &K       | = Lot Code                |
| CQXX65RT | = Specific Device Code    |
| XX       | = 07, 09, 12, 15          |

### ORDERING INFORMATION

See detailed ordering and shipping information on page 31 of this data sheet.

## FSCQ Series

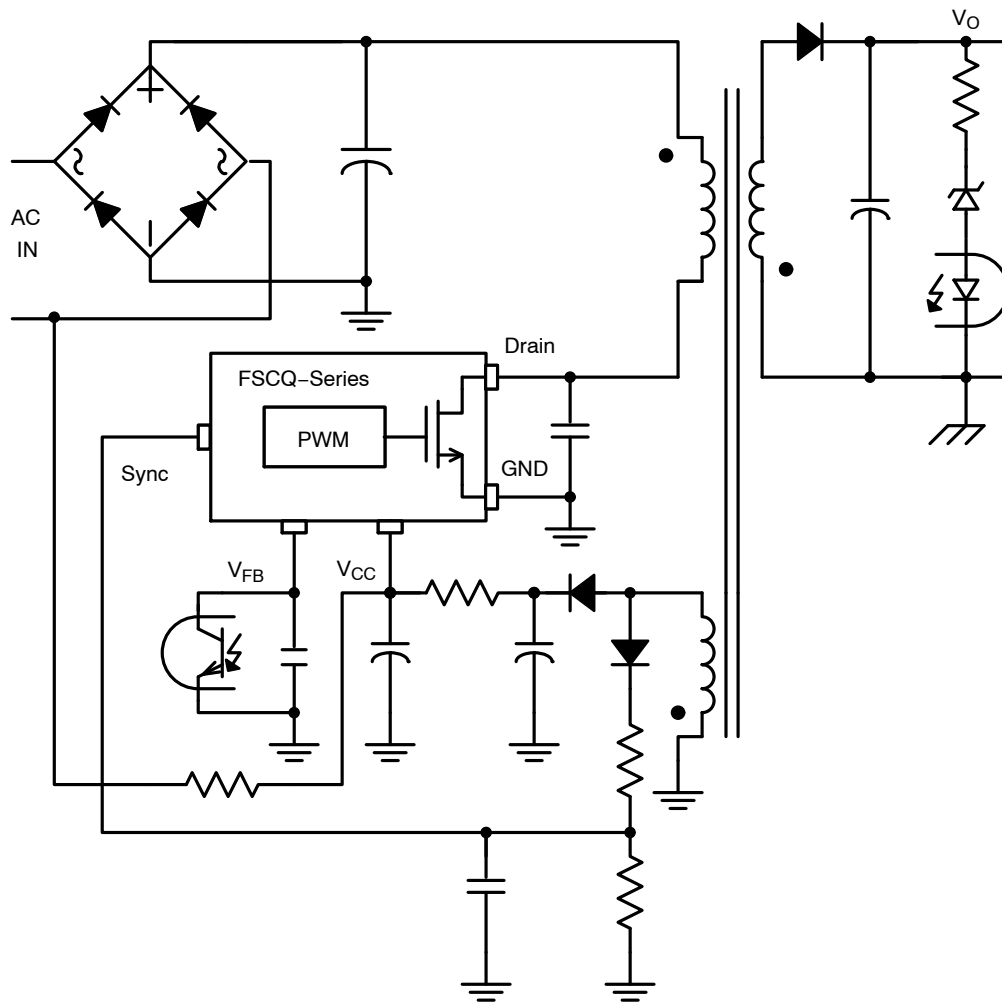


Figure 1. Typical Flyback Application

Table 1. MAXIMUM OUTPUT POWER (Note 1)

|            | 230 V <sub>AC</sub> ±15% (Note 2) | 85–265 V <sub>AC</sub> |
|------------|-----------------------------------|------------------------|
| Product    | Open Frame (Note 3)               | Open Frame (Note 3)    |
| FSCQ0765RT | 100 W                             | 85 W                   |
| FSCQ0965RT | 130 W                             | 110 W                  |
| FSCQ1265RT | 170 W                             | 140 W                  |
| FSCQ1565RT | 210 W                             | 170 W                  |

1. The junction temperature can limit the maximum output power.
2. 230 V<sub>AC</sub> or 100/115 V<sub>AC</sub> with doubler.
3. Maximum practical continuous power in an open frame design at 50°C ambient.

# FSCQ Series

## Internal Block Diagram

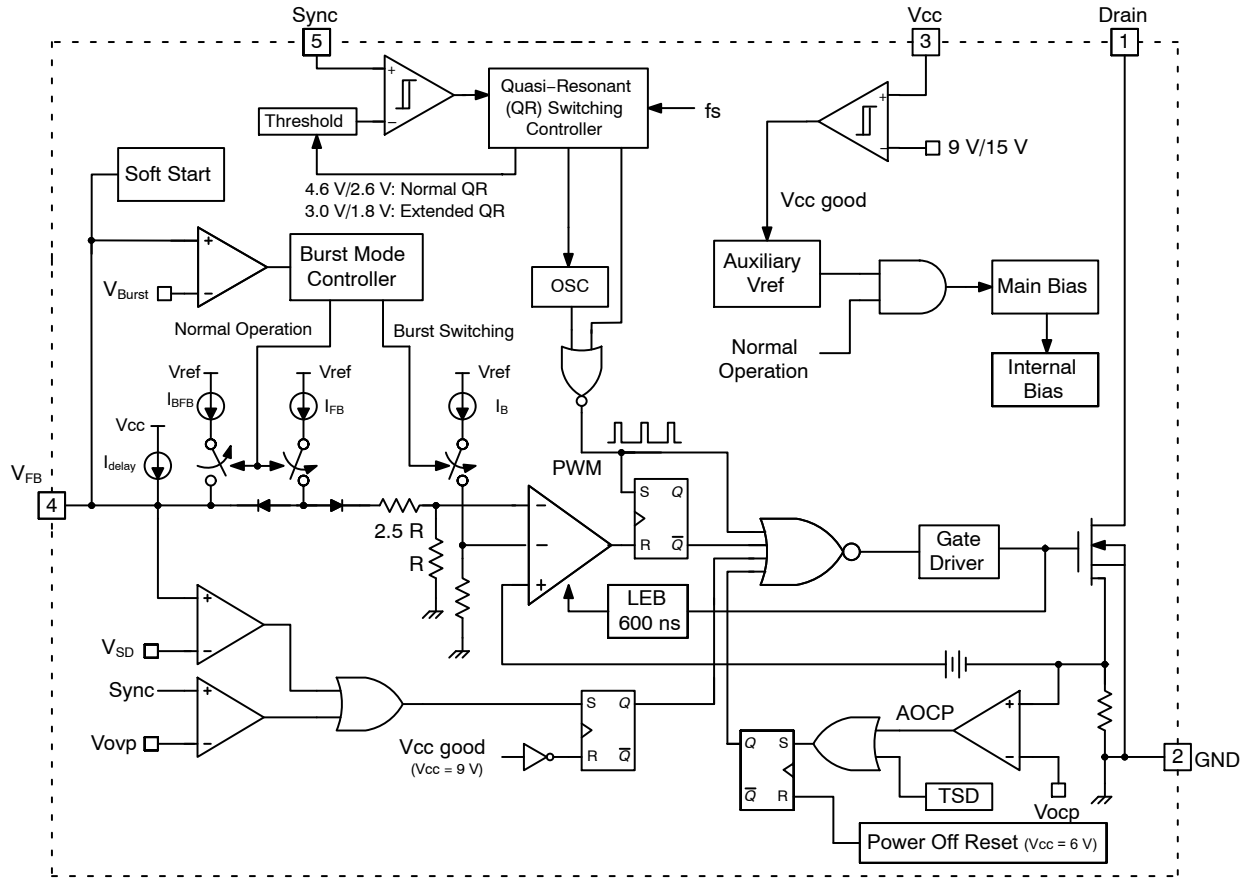


Figure 2. Functional Block Diagram

## FSCQ Series

### Pin Configuration

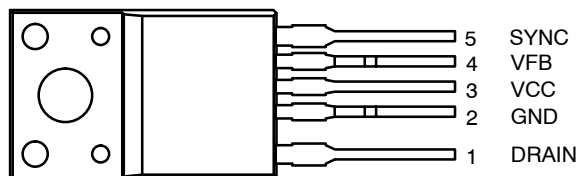


Figure 3. Pin Assignments (Top View)

### PIN DESCRIPTION

| Pin No. | Symbol | Description                                                                                                                                                                                                                                                                                                                                      |
|---------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | DRAIN  | This pin is the high-voltage power SENSEFET drain connection.                                                                                                                                                                                                                                                                                    |
| 2       | GND    | This pin is the control ground and the SENSEFET source.                                                                                                                                                                                                                                                                                          |
| 3       | VCC    | This pin is the positive supply input. This pin provides internal operating current for both startup and steady-state operation.                                                                                                                                                                                                                 |
| 4       | VFB    | This pin is internally connected to the inverting input of the PWM comparator. The collector of an opto-coupler is typically tied to this pin. For stable operation, a capacitor should be placed between this pin and GND. If the voltage of this pin reaches 7.5 V, the overload protection triggers, which results in the FPS] shutting down. |
| 5       | SYNC   | This pin is internally connected to the sync detect comparator for quasi-resonant switching. In normal quasi-resonant operation, the threshold of the sync comparator is 4.6 V / 2.6 V. Whereas, the sync threshold is changed to 3.0 V / 1.8 V in an extended quasi-resonant operation.                                                         |

### ABSOLUTE MAXIMUM RATINGS (T<sub>A</sub> = 25°C unless otherwise specified)

| Parameter                                                                                               |            | Symbol            | Value                   | Unit               |
|---------------------------------------------------------------------------------------------------------|------------|-------------------|-------------------------|--------------------|
| Drain Pin Voltage                                                                                       |            | V <sub>DS</sub>   | 650                     | V                  |
| Supply Voltage                                                                                          |            | V <sub>CC</sub>   | 20                      | V                  |
| Analog Input Voltage Range                                                                              |            | V <sub>sync</sub> | -0.3 to 13              | V                  |
|                                                                                                         |            | V <sub>Fb</sub>   | -0.3 to V <sub>CC</sub> |                    |
| Drain Current Pulsed (Note 4)                                                                           | FSCQ0765RT | I <sub>DM</sub>   | 15.2                    | A                  |
|                                                                                                         | FSCQ0965RT |                   | 16.4                    |                    |
|                                                                                                         | FSCQ1265RT |                   | 21.2                    |                    |
|                                                                                                         | FSCQ1565RT |                   | 26.4                    |                    |
| Continuous Drain Current (T <sub>C</sub> = 25°C)<br>(T <sub>C</sub> : Case Back Surface Temperature)    | FSCQ0765RT | I <sub>D</sub>    | 3.8                     | A <sub>(rms)</sub> |
|                                                                                                         | FSCQ0965RT |                   | 4.1                     |                    |
|                                                                                                         | FSCQ1265RT |                   | 5.3                     |                    |
|                                                                                                         | FSCQ1565RT |                   | 6.6                     |                    |
| Continuous Drain Current* (T <sub>DL</sub> = 25°C)<br>(T <sub>DL</sub> : Case Back Surface Temperature) | FSCQ0765RT | I <sub>D</sub> *  | 7.0                     | A <sub>(rms)</sub> |
|                                                                                                         | FSCQ0965RT |                   | 7.6                     |                    |
|                                                                                                         | FSCQ1265RT |                   | 11.0                    |                    |
|                                                                                                         | FSCQ1565RT |                   | 13.3                    |                    |
| Continuous Drain Current (T <sub>C</sub> = 100°C)                                                       | FSCQ0765RT | I <sub>D</sub>    | 2.4                     | A <sub>(rms)</sub> |
|                                                                                                         | FSCQ0965RT |                   | 2.6                     |                    |
|                                                                                                         | FSCQ1265RT |                   | 3.4                     |                    |
|                                                                                                         | FSCQ1565RT |                   | 4.4                     |                    |

## FSCQ Series

### ABSOLUTE MAXIMUM RATINGS ( $T_A = 25^\circ\text{C}$ unless otherwise specified) (continued)

| Parameter                                                                   |                                   | Symbol    | Value       | Unit             |
|-----------------------------------------------------------------------------|-----------------------------------|-----------|-------------|------------------|
| Single-Pulsed Avalanche Energy (Note 5)                                     | FSCQ0765RT                        | $E_{AS}$  | 570         | mJ               |
|                                                                             | FSCQ0965RT                        |           | 630         |                  |
|                                                                             | FSCQ1265RT                        |           | 950         |                  |
|                                                                             | FSCQ1565RT                        |           | 1050        |                  |
| Total Power Dissipation ( $T_C = 25^\circ\text{C}$ with Infinite Heat Sink) | FSCQ0765RT                        | $P_D$     | 45          | W                |
|                                                                             | FSCQ0965RT                        |           | 49          |                  |
|                                                                             | FSCQ1265RT                        |           | 50          |                  |
|                                                                             | FSCQ1565RT                        |           | 75          |                  |
| Operating Junction Temperature                                              |                                   | $T_J$     | 150         | $^\circ\text{C}$ |
| Operating Ambient Temperature                                               |                                   | $T_A$     | -25 to +85  | $^\circ\text{C}$ |
| Storage Temperature Range                                                   |                                   | $T_{STG}$ | -55 to +150 | $^\circ\text{C}$ |
| Human Body Model (All Pins Except $V_{FB}$ )                                | (GND - $V_{FB} = 1.7\text{ kV}$ ) | ESD       | 2.0         | kV               |
| Machine Model (All Pins Except $V_{FB}$ )                                   | (GND - $V_{FB} = 170\text{ V}$ )  |           | 300         | V                |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

4. Repetitive rating: pulse width limited by maximum junction temperature.

5.  $L = 15\text{ mH}$ , starting  $T_J = 25^\circ\text{C}$ . These parameters, although guaranteed by design, are not tested in production.

### THERMAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)

| Characteristic                     | Characteristic | Symbol | Value | Unit               |
|------------------------------------|----------------|--------|-------|--------------------|
| Junction-to Case Thermal Impedance | FSCQ0765RT     | $J_C$  | 2.60  | $^\circ\text{C/W}$ |
|                                    | FSCQ0965RT     |        | 2.55  |                    |
|                                    | FSCQ1265RT     |        | 2.50  |                    |
|                                    | FSCQ1565RT     |        | 2.00  |                    |

## FSCQ Series

### ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise specified)

| Symbol | Parameter | Test Condition | Min | Typ | Max | Unit |
|--------|-----------|----------------|-----|-----|-----|------|
|--------|-----------|----------------|-----|-----|-----|------|

#### SENSEFET PART

|                     |                                  |                                                                           |     |      |      |    |
|---------------------|----------------------------------|---------------------------------------------------------------------------|-----|------|------|----|
| BV <sub>DSS</sub>   | Drain-Source Breakdown Voltage   | V <sub>GS</sub> = 0 V, I <sub>D</sub> = 250 μA                            | 650 | –    | –    | V  |
| I <sub>DSS</sub>    | Zero Gate Voltage Drain Current  | V <sub>DS</sub> = 650 V, V <sub>GS</sub> = 0 V                            | –   | –    | 250  | μA |
| R <sub>DS(ON)</sub> | Drain-Source On-State Resistance | FSCQ0765RT<br>V <sub>GS</sub> = 10 V, I <sub>D</sub> = 1 A                | –   | 1.40 | 1.60 | Ω  |
|                     |                                  | FSCQ0965RT<br>V <sub>GS</sub> = 10 V, I <sub>D</sub> = 1 A                | –   | 1.00 | 1.20 |    |
|                     |                                  | FSCQ1265RT<br>V <sub>GS</sub> = 10 V, I <sub>D</sub> = 1 A                | –   | 0.75 | 0.90 |    |
|                     |                                  | FSCQ1565RT<br>V <sub>GS</sub> = 10 V, I <sub>D</sub> = 1 A                | –   | 0.53 | 0.70 |    |
| C <sub>ISS</sub>    | Input Capacitance                | FSCQ0765RT<br>V <sub>GS</sub> = 0 V, V <sub>DS</sub> = 25 V,<br>f = 1 MHz | –   | 1415 | –    | pF |
|                     |                                  | FSCQ0965RT                                                                | –   | 1750 | –    |    |
|                     |                                  | FSCQ1265RT                                                                | –   | 2400 | –    |    |
|                     |                                  | FSCQ1565RT                                                                | –   | 3050 | –    |    |
| C <sub>OSS</sub>    | Output Capacitance               | FSCQ0765RT<br>V <sub>GS</sub> = 0 V, V <sub>DS</sub> = 25 V,<br>f = 1 MHz | –   | 100  | –    | pF |
|                     |                                  | FSCQ0965RT                                                                | –   | 130  | –    |    |
|                     |                                  | FSCQ1265RT                                                                | –   | 175  | –    |    |
|                     |                                  | FSCQ1565RT                                                                | –   | 220  | –    |    |

#### CONTROL SECTION

|                    |                                        |                                                 |      |      |      |     |
|--------------------|----------------------------------------|-------------------------------------------------|------|------|------|-----|
| f <sub>OSC</sub>   | Switching Frequency                    | V <sub>FB</sub> = 5 V, V <sub>CC</sub> = 18 V   | 18   | 20   | 22   | kHz |
| Δf <sub>OSC</sub>  | Switching Frequency Variation (Note 7) | –25°C ≤ T <sub>A</sub> ≤ 85°C                   | 0    | ±5   | ±10  | %   |
| I <sub>FB</sub>    | Feedback Source Current                | V <sub>FB</sub> = 0.8 V, V <sub>CC</sub> = 18 V | 0.50 | 0.65 | 0.80 | mA  |
| D <sub>MAX</sub>   | Maximum Duty Cycle                     | V <sub>FB</sub> = 5 V, V <sub>CC</sub> = 18 V   | 92   | 95   | 98   | %   |
| D <sub>MIN</sub>   | Minimum Duty Cycle                     | V <sub>FB</sub> = 0 V, V <sub>CC</sub> = 18 V   | –    | 0    | –    | %   |
| V <sub>START</sub> | UVLO Threshold Voltage                 | V <sub>FB</sub> = 1 V                           | 14   | 15   | 16   | V   |
| V <sub>STOP</sub>  |                                        |                                                 | 8    | 9    | 10   |     |
| t <sub>SS</sub>    | Soft-Start Time (Note 6)               |                                                 | 18   | 20   | 22   | ms  |

#### BURST MODE SECTION

|                  |                                    |                                     |      |      |      |    |
|------------------|------------------------------------|-------------------------------------|------|------|------|----|
| V <sub>BEN</sub> | Burst Mode Enable Feedback Voltage |                                     | 0.25 | 0.40 | 0.55 | V  |
| I <sub>BFB</sub> | Burst Mode Feedback Source Current | V <sub>FB</sub> = 0 V               | 60   | 100  | 140  | μA |
| t <sub>BS</sub>  | Burst Mode Switching Time          | V <sub>FB</sub> = 0.9 V, Duty = 50% | 1.2  | 1.4  | 1.6  | ms |
| t <sub>BH</sub>  | Burst Mode Hold Time               | V <sub>FB</sub> = 0.9 V → 0 V       | 1.2  | 1.4  | 1.6  | ms |

#### PROTECTION SECTION

|                    |                                       |                                               |     |     |     |    |
|--------------------|---------------------------------------|-----------------------------------------------|-----|-----|-----|----|
| V <sub>SD</sub>    | Shutdown Feedback Voltage             | V <sub>CC</sub> = 18 V                        | 7.0 | 7.5 | 8.0 | V  |
| I <sub>DELAY</sub> | Shutdown Delay Current                | V <sub>FB</sub> = 5 V, V <sub>CC</sub> = 18 V | 4   | 5   | 6   | μA |
| V <sub>OVP</sub>   | Over-Voltage Protection               | V <sub>FB</sub> = 3 V                         | 11  | 12  | 13  | V  |
| V <sub>OCL</sub>   | Over-Current Latch Voltage (Note 6)   | V <sub>CC</sub> = 18 V                        | 0.9 | 1.0 | 1.1 | V  |
| TSD                | Thermal Shutdown Temperature (Note 7) |                                               | 140 | –   | –   | °C |

#### SYNC SECTION

|                  |                                   |                                               |     |     |     |     |
|------------------|-----------------------------------|-----------------------------------------------|-----|-----|-----|-----|
| V <sub>SH1</sub> | Sync Threshold in Normal QR (H)   | V <sub>CC</sub> = 18 V, V <sub>FB</sub> = 5 V | 4.2 | 4.6 | 5.0 | V   |
| V <sub>SL1</sub> | Sync Threshold in Normal QR (L)   |                                               | 2.3 | 2.6 | 2.9 | V   |
| V <sub>SH2</sub> | Sync Threshold in Extended QR (H) |                                               | 2.7 | 3.0 | 3.3 | V   |
| V <sub>SL2</sub> | Sync Threshold in Extended QR (L) |                                               | 1.6 | 1.8 | 2.0 | V   |
| f <sub>SYH</sub> | Extended QR Enable Frequency      |                                               | –   | 90  | –   | kHz |
| f <sub>SYL</sub> | Extended QR Disable Frequency     |                                               | –   | 45  | –   | kHz |

## FSCQ Series

### ELECTRICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise specified) (continued)

| Symbol               | Parameter                                                       | Test Condition                               | Min                   | Typ  | Max  | Unit |    |
|----------------------|-----------------------------------------------------------------|----------------------------------------------|-----------------------|------|------|------|----|
| TOTAL DEVICE SECTION |                                                                 |                                              |                       |      |      |      |    |
| I <sub>OP</sub>      | Operating Supply Current in Normal Operation (Note 8)           | FSCQ0765RT                                   | V <sub>FB</sub> = 5 V | –    | 4    | 6    | mA |
|                      |                                                                 | FSCQ0965RT                                   |                       | –    | 6    | 8    |    |
|                      |                                                                 | FSCQ1265RT                                   |                       | –    | 6    | 8    |    |
|                      |                                                                 | FSCQ1565RT                                   |                       | –    | 7    | 9    |    |
| I <sub>OB</sub>      | Operating Supply Current in Burst Mode (Non–Switching) (Note 8) | V <sub>FB</sub> = GND                        | –                     | 0.25 | 0.50 | mA   |    |
| I <sub>START</sub>   | Startup Current                                                 | V <sub>CC</sub> = V <sub>START</sub> – 0.1 V | –                     | 25   | 50   | μA   |    |
| I <sub>SN</sub>      | Sustain Latch Current (Note 6)                                  | V <sub>CC</sub> = V <sub>STOP</sub> – 0.1 V  | –                     | 50   | 100  | μA   |    |

### CURRENT SENSE SECTION

|               |                                |            |                                               |      |      |      |   |
|---------------|--------------------------------|------------|-----------------------------------------------|------|------|------|---|
| $I_{LIM}$     | Maximum Current Limit (Note 9) | FSCQ0765RT | $V_{CC} = 18\text{ V}, V_{FB} = 5\text{ V}$   | 4.40 | 5.00 | 5.60 | A |
|               |                                | FSCQ0965RT |                                               | 5.28 | 6.00 | 6.72 |   |
|               |                                | FSCQ1265RT |                                               | 6.16 | 7.00 | 7.84 |   |
|               |                                | FSCQ1565RT |                                               | 7.04 | 8.00 | 8.96 |   |
| $I_{BUR(pk)}$ | Burst Peak Current             | FSCQ0765RT | $V_{CC} = 18\text{ V}, V_{FB} = \text{Pulse}$ | 0.65 | 0.90 | 1.15 | A |
|               |                                | FSCQ0965RT |                                               | 0.60 | 0.90 | 1.20 |   |
|               |                                | FSCQ1265RT |                                               | 0.80 | 1.20 | 1.60 |   |
|               |                                | FSCQ1565RT |                                               | –    | 1.00 | –    |   |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

6. These parameters, although guaranteed, are tested only in wafer test process.

7. These parameters, although guaranteed by design, are not tested in production.

8. This parameter is the current flowing in the control IC.

9. These parameters indicate inductor current.

10. These parameters, although guaranteed, are tested only in wafer test process.

## FSCQ Series

### TYPICAL PERFORMANCE CHARACTERISTICS

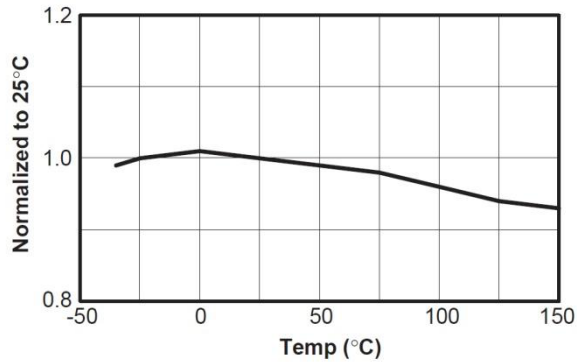


Figure 4. Operating Supply Current

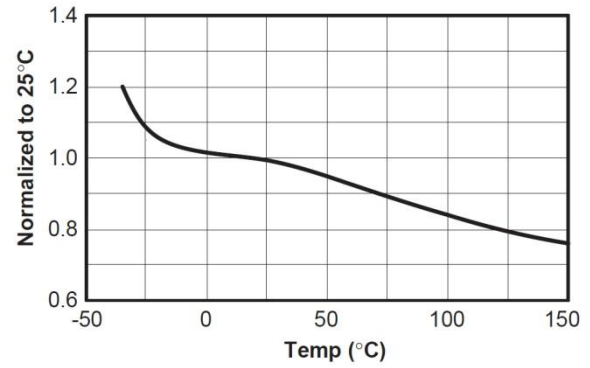


Figure 5. Burst Mode Supply Current (Non-Switching)

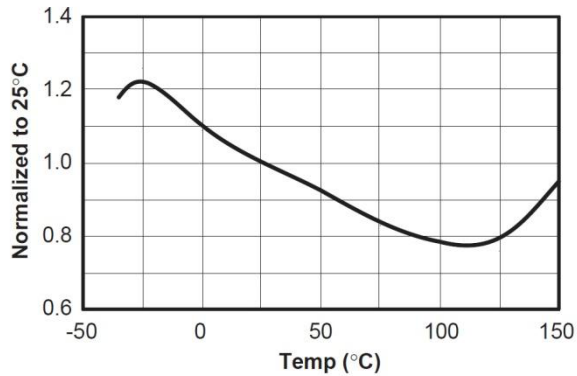


Figure 6. Startup Current

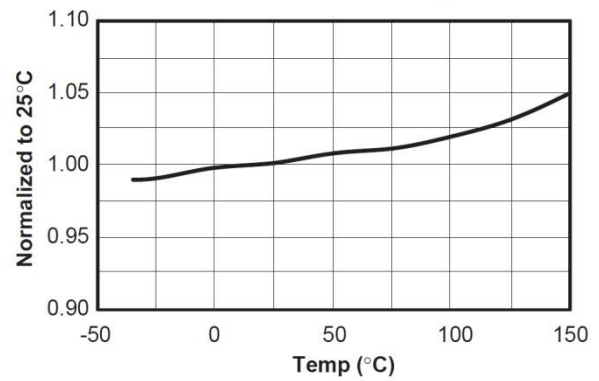


Figure 7. Start Threshold Voltage

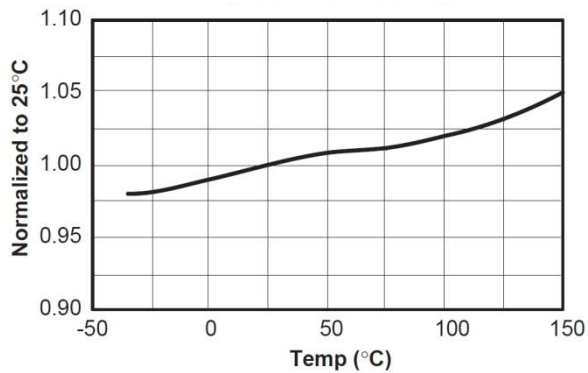


Figure 8. Stop Threshold Voltage

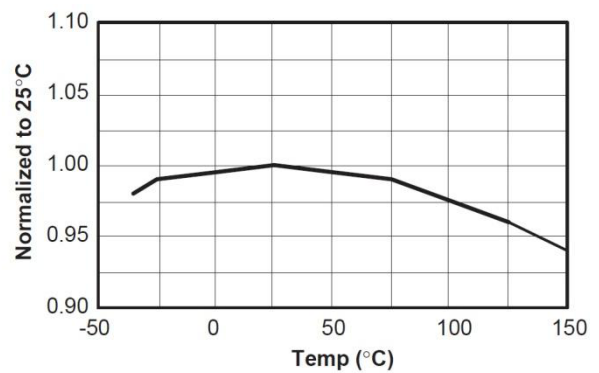


Figure 9. Initial Frequency

## FSCQ Series

### TYPICAL PERFORMANCE CHARACTERISTICS (continued)

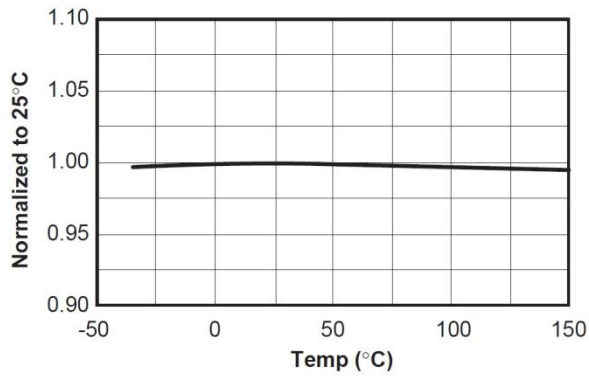


Figure 10. Maximum Duty Cycle

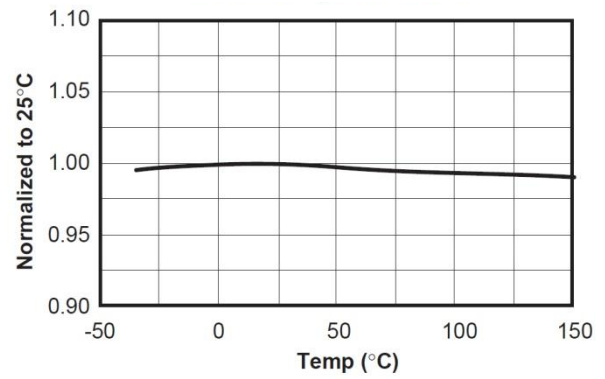


Figure 11. Over-Voltage Protection

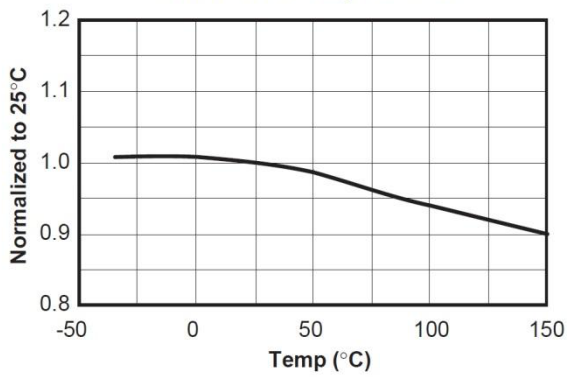


Figure 12. Shutdown Delay Current

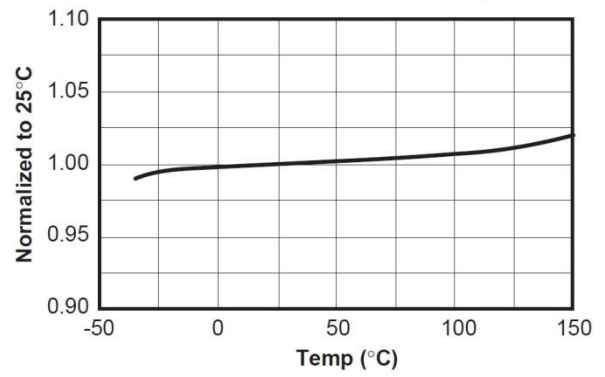


Figure 13. Shutdown Feedback Voltage

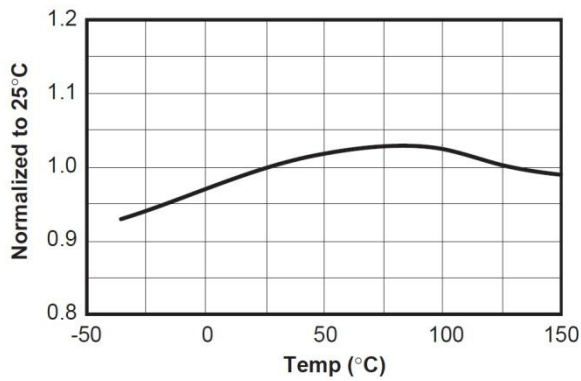


Figure 14. Feedback Source Current

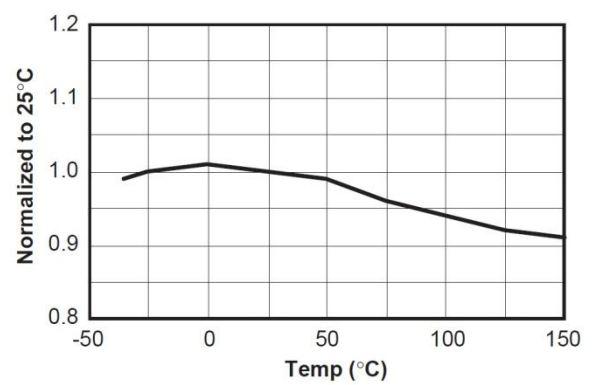


Figure 15. Burst Mode Feedback Source Current

## FSCQ Series

### TYPICAL PERFORMANCE CHARACTERISTICS (continued)

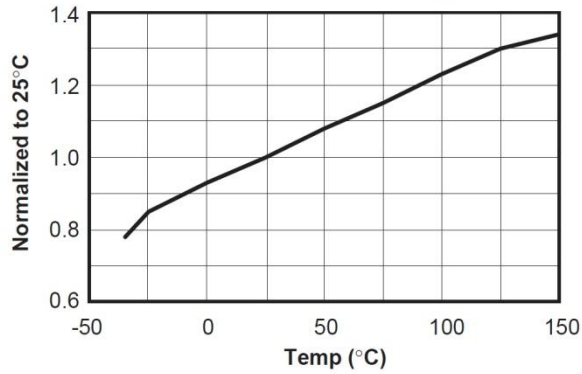


Figure 16. Feedback Offset Voltage

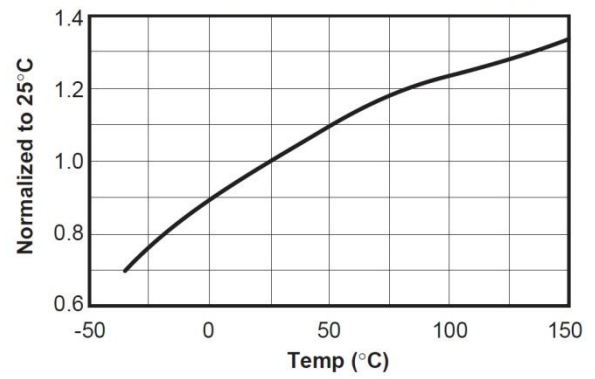


Figure 17. Burst Mode Enable Feedback Voltage

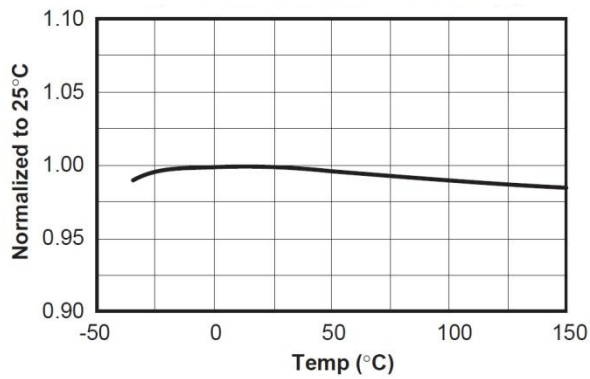


Figure 18. Sync. Threshold in Normal QR(H)

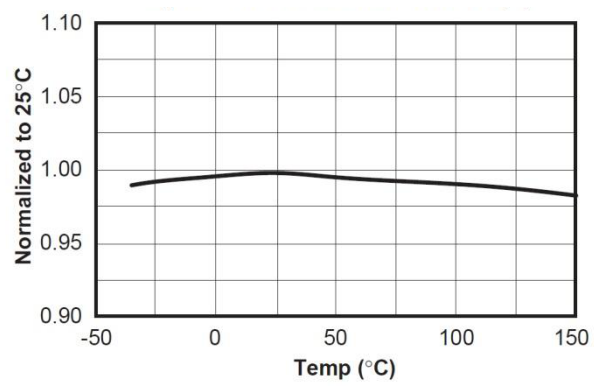


Figure 19. Sync. Threshold in Normal QR(L)

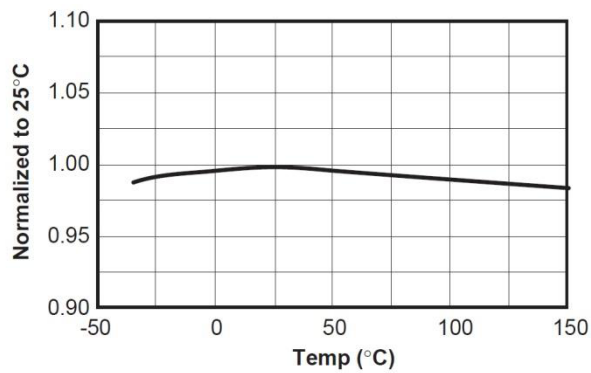


Figure 20. Sync. Threshold in Extended QR(H)

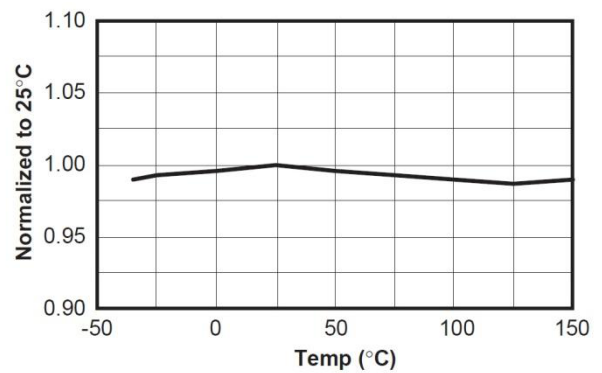


Figure 21. Sync. Threshold in Extended QR(L)

## FSCQ Series

### TYPICAL PERFORMANCE CHARACTERISTICS (continued)

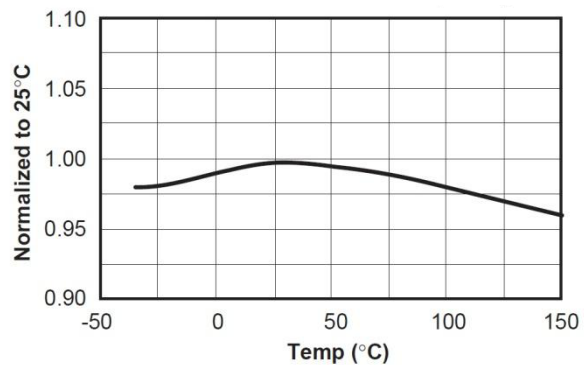


Figure 22. Extended QR Enable Frequency

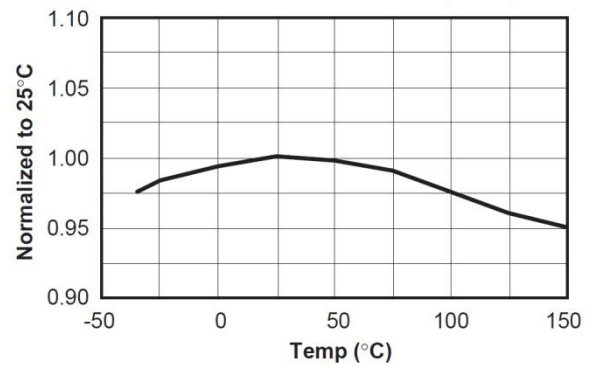


Figure 23. Extended QR Disable Frequency

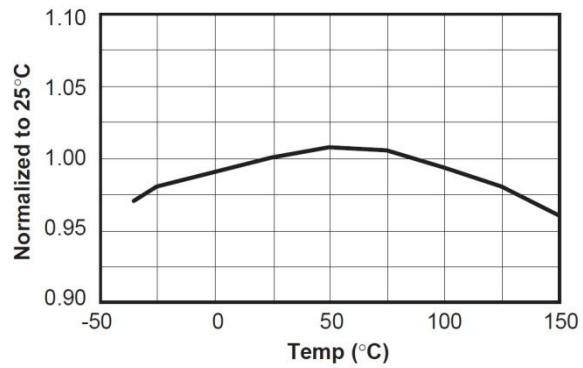


Figure 24. Pulse-by-Pulse Current Limit

## Functional Description

### Startup

Figure 25 shows the typical startup circuit and the transformer auxiliary winding for the FSCQ series. Before the FSCQ series begins switching, it consumes only startup current (typically 25  $\mu$ A). The current supplied from the AC line charges the external capacitor ( $C_{a1}$ ) that is connected to the  $V_{CC}$  pin. When  $V_{CC}$  reaches the start voltage of 15 V ( $V_{START}$ ), the FSCQ series begins switching and its current consumption increases to  $I_{OP}$ . Then, the FSCQ series continues normal switching operation and the power required is supplied from the transformer auxiliary winding, unless  $V_{CC}$  drops below the stop voltage of 9 V ( $V_{STOP}$ ). To guarantee stable operation of the control IC,  $V_{CC}$  has under-voltage lockout (UVLO) with 6 V hysteresis. Figure 26 shows the relationship between the operating supply current of the FSCQ series and the supply voltage ( $V_{CC}$ ).

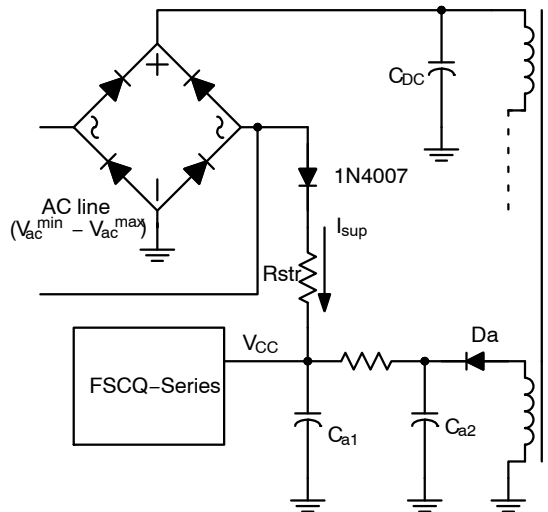


Figure 25. Startup Circuit

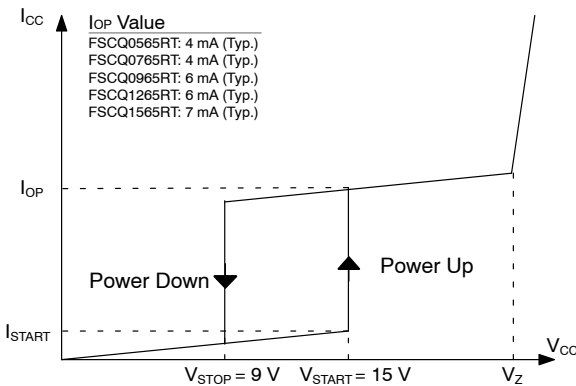


Figure 26. Relationship between Operating Supply Current and  $V_{CC}$  Voltage

The minimum average of the current supplied from the AC is given by:

$$I_{SUP}^{AVG} = \left( \frac{\sqrt{2 \cdot V_{AC}^{MIN}}}{\pi} - \frac{V_{START}}{2} \right) \cdot \frac{1}{R_{STR}} \quad (\text{eq. 1})$$

where  $V_{ac}^{min}$  is the minimum input voltage,  $V_{START}$  is the FSCQ series' start voltage (15 V), and  $R_{STR}$  is the startup resistor. The startup resistor should be chosen so that  $I_{sup}^{avg}$  is larger than the maximum startup current (50 mA).

Once the resistor value is determined, the maximum loss in the startup resistor is obtained as:

$$Loss = \frac{1}{R_{STR}} \cdot \left[ \frac{(V_{AC}^{MAX})^2 + V_{START}^2}{2} - \frac{2\sqrt{2} \cdot V_{START} \cdot V_{AC}^{MAX}}{\pi} \right] \quad (\text{eq. 2})$$

where  $V_{ac}^{max}$  is the maximum input voltage.

The startup resistor should have properly rated dissipation wattage.

### Synchronization

The FSCQ series employs a quasi-resonant switching technique to minimize the switching noise and loss. In this technique, a capacitor ( $C_r$ ) is added between the MOSFET drain and the source, as shown in Figure 27. The basic waveforms of the quasi-resonant converter are shown in Figure 28. The external capacitor lowers the rising slope of the drain voltage to reduce the EMI caused when the MOSFET turns off. To minimize the MOSFET's switching loss, the MOSFET should be turned on when the drain voltage reaches its minimum value, as shown in Figure 28.

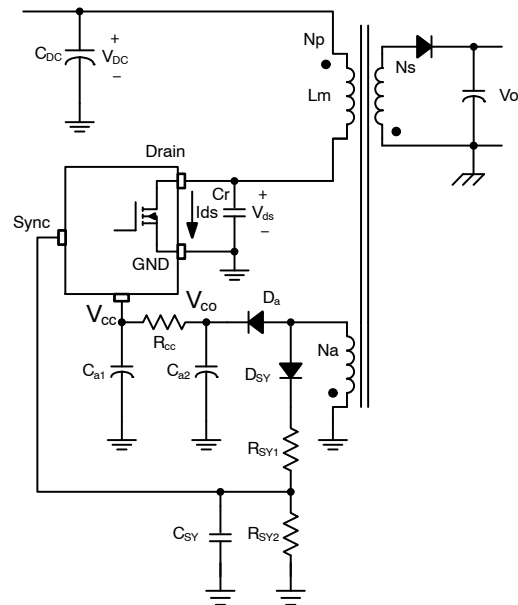


Figure 27. Synchronization Circuit

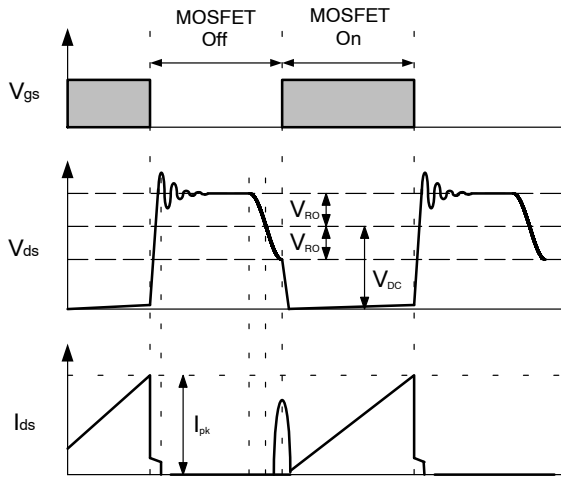


Figure 28. Quasi-Resonant Operation Waveforms

The minimum drain voltage is indirectly detected by monitoring the  $V_{CC}$  winding voltage, as shown in Figure 27 and Figure 29. Choose voltage dividers,  $R_{SY1}$  and  $R_{SY2}$ , so that the peak voltage of the sync signal ( $V_{syph}$ ) is lower than the OVP voltage (12 V) to avoid triggering OVP in normal operation. It is typical to set  $V_{syph}$  to be lower than OVP voltage by 3–4 V. To detect the optimum time to turn on MOSFET, the sync capacitor ( $C_{SY}$ ) should be determined so that  $t_R$  is the same with  $t_Q$ , as shown in Figure 29. The  $t_R$  and  $t_Q$  are given as:

$$t_R = R_{SY2} \cdot C_{SY} \cdot \ln \left( \frac{V_{CO}}{2.6} \cdot \frac{R_{SY2}}{R_{SY1} + R_{SY2}} \right) \quad (\text{eq. 3})$$

$$t_Q = \pi \cdot \sqrt{L_m \cdot C_{eo}} \quad (\text{eq. 4})$$

$$V_{CO} = \frac{N_a \cdot (V_O + V_{FO})}{N_s} - V_{Fa} \quad (\text{eq. 5})$$

where:

- $L_m$  is the primary side inductance of the transformer,
- $N_s$  is the number of turns for the output winding,
- $N_a$  is the number of turns for the  $V_{CC}$  winding,
- $V_{FO}$  is the diode forward-voltage drop of the output winding,
- $V_{Fa}$  is the diode forward-voltage drop of the  $V_{CC}$  winding; and
- $C_{eo}$  is the sum of the output capacitance of the MOSFET and the external capacitor,  $C_T$ .

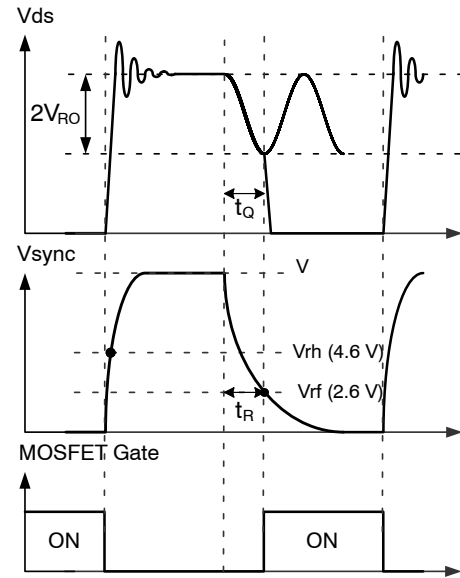


Figure 29. Normal QR Operation Waveforms

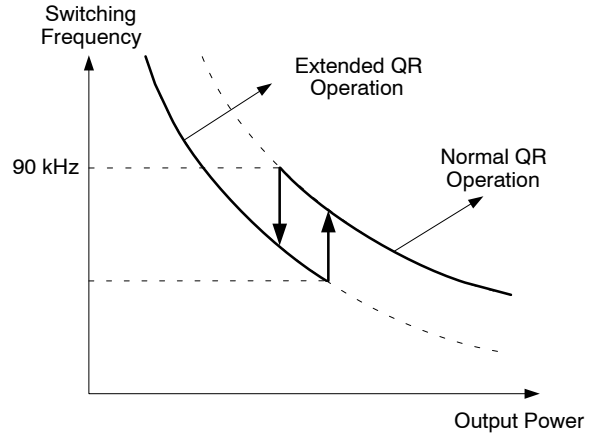
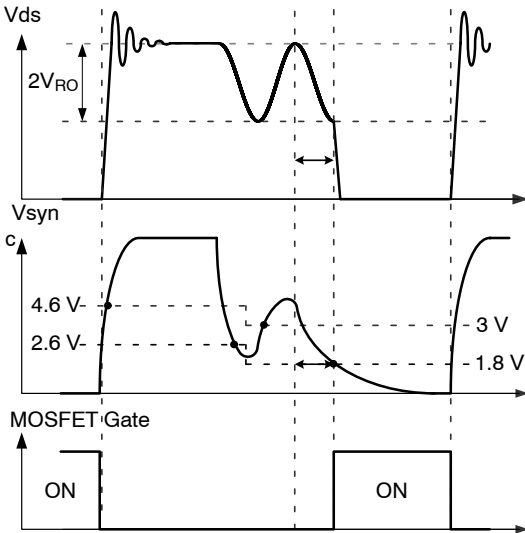


Figure 30. Extended Quasi-Resonant Operation

In general, the QRC has a limitation in a wide load range application, since the switching frequency increases as the output load decreases, resulting in a severe switching loss in the light load condition. To overcome this limitation, the FSCQ series employs an extended quasi-resonant switching operation. Figure 30 shows the mode change between normal and extended quasi-resonant operations. In the normal quasi-resonant operation, the FSCQ series enters into the extended quasi-resonant operation when the switching frequency exceeds 90 kHz as the load reduces. To reduce the switching frequency, the MOSFET is turned on when the drain voltage reaches the second minimum level,

as shown in Figure 31. Once the FSCQ series enters into the extended quasi-resonant operation, the first sync signal is ignored. After the first sync signal is applied, the sync threshold levels are changed from 4.6 V and 2.6 V to 3 V and 1.8 V, respectively, and the MOSFET turn-on time is synchronized to the second sync signal. The FSCQ series returns to its normal quasi-resonant operation when the switching frequency reaches 45 kHz as the load increases.



**Figure 31. Extended QR Operation Waveforms**

## Feedback Control

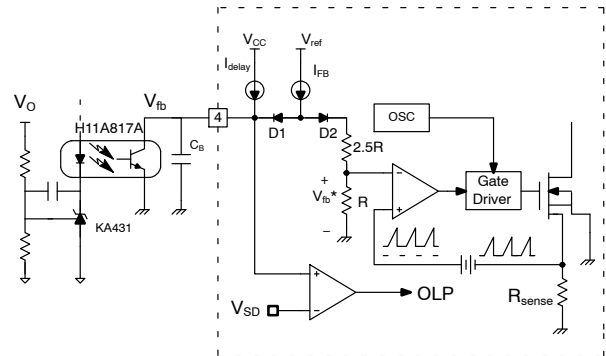
The FSCQ series employs current mode control, as shown in Figure 32. An optocoupler (such as **onsemi's** H11A817A) and shunt regulator (such as **onsemi's** KA431) are typically used to implement the feedback network. Comparing the feedback voltage with the voltage across the  $R_{sense}$  resistor, plus an offset voltage, makes it possible to control the switching duty cycle. When the reference pin voltage of the shunt regulator exceeds the internal reference voltage of 2.5 V, the opto-coupler LED current increases, pulling down the feedback voltage and reducing the duty cycle. This typically occurs when input voltage is increased or output load is decreased.

## Pulse-by-Pulse Current Limit

Because current mode control is employed, the peak current through the SENSEFET is limited by the inverting input of the PWM comparator ( $V_{fb}^*$ ) as shown in Figure 32. The feedback current ( $I_{FB}$ ) and internal resistors are designed so that the maximum cathode voltage of diode  $D_2$  is about 2.8 V, which occurs when all  $I_{FB}$  flows through the internal resistors. Since  $D_1$  is blocked when the feedback voltage ( $V_{fb}$ ) exceeds 2.8 V, the maximum voltage of the cathode of  $D_2$  is clamped at this voltage, thus clamping  $V_{fb}^*$ . Therefore, the peak value of the current through the SENSEFET is limited.

## Leading Edge Blanking (LEB)

At the instant the internal SENSEFET is turned on, there is usually a high current spike through the SENSEFET, caused by the external resonant capacitor across the MOSFET and secondary-side rectifier reverse recovery. Excessive voltage across the  $R_{sense}$  resistor can lead to incorrect feedback operation in the current mode PWM control. To counter this effect, the FSCQ series employs a leading edge blanking (LEB) circuit. This circuit inhibits the PWM comparator for a short time ( $t_{LEB}$ ) after the Sense FET is turned on.



**Figure 32. Pulse Width Modulation (PWM) Circuit**

## Protection Circuits

The FSCQ series has several self-protective functions such as overload protection (OLP), abnormal over-current protection (AOCP), overvoltage protection (OVP), and thermal shutdown (TSD). OLP and OVP are auto-restart mode protections, while TSD and AOCP are latch mode protections. Because these protection circuits are fully integrated into the IC without external components, the reliability can be improved without increasing cost.

- **Auto-Restart Mode Protection:** Once the fault condition is detected, switching is terminated and the SENSEFET remains off. This causes  $V_{CC}$  to fall. When  $V_{CC}$  falls to the under voltage lockout (UVLO) stop voltage of 9 V, the protection is reset and the FSCQ series consumes only startup current (25 mA). Then, the  $V_{CC}$  capacitor is charged up, since the current supplied through the startup resistor is larger than the current that the FPS consumes. When  $V_{CC}$  reaches the start voltage of 15 V, the FSCQ series resumes its normal operation. If the fault condition is not removed, the SENSEFET remains off and  $V_{CC}$  drops to stop voltage again. In this manner, the auto-restart can alternately enable and disable the switching of the power SENSEFET until the fault condition is eliminated (see Figure 33).
- **Latch Mode Protection:** Once this protection is triggered, switching is terminated and the SENSEFET remains off until the AC power line is unplugged. Then,  $V_{CC}$  continues charging and discharging between 9 V and 15 V. The latch is reset only when  $V_{CC}$  is discharged to 6 V by unplugging the AC power line.

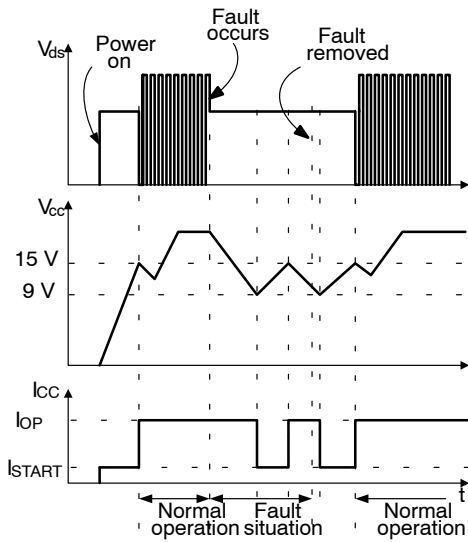


Figure 33. Auto Restart Mode Protection

#### Overload Protection (OLP)

Overload is defined as the load current exceeding its normal level due to an unexpected abnormal event. In this situation, the protection circuit should trigger to protect the SMPS. However, even when the SMPS is in the normal operation, the over load protection circuit can be triggered during the load transition. To avoid this undesired operation, the overload protection circuit is designed to trigger after a specified time to determine whether it is a transient situation or an overload situation. Because of the pulse-by-pulse current limit capability, the maximum peak current through the SENSEFET is limited, and therefore the maximum input power is restricted with a given input voltage. If the output consumes more than this maximum power, the output voltage ( $V_o$ ) decreases below the set voltage. This reduces the current through the opto-coupler LED, which also reduces the opto-coupler transistor current, thus increasing the feedback voltage ( $V_{fb}$ ). If  $V_{fb}$  exceeds 2.8 V,  $D_1$  is blocked, and the 5  $\mu$ A current source starts to charge  $C_B$  slowly up to  $V_{CC}$ . In this condition,  $V_{fb}$  continues increasing until it reaches 7.5 V, then the switching operation is terminated as shown in Figure 34. The delay for shutdown is the time required to charge  $C_B$  from 2.8 V to 7.5 V with 5  $\mu$ A. In general, a 20~50 ms delay is typical for most applications. OLP is implemented in auto restart mode.

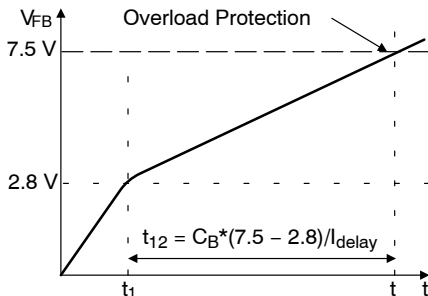


Figure 34. Overload Protection

#### Abnormal Over Current Protection (AOCP)

When the secondary rectifier diodes or the transformer pins are shorted, a steep current with extremely high di/dt can flow through the SENSEFET during the LEB time. Even though the FSCQ series has OLP (Overload Protection), it is not enough to protect the FSCQ series in that abnormal case, since severe current stress will be imposed on the SENSEFET until the OLP triggers. The FSCQ series has an internal AOCP (Abnormal Over-Current Protection) circuit as shown in Figure 35. When the gate turn-on signal is applied to the power SENSEFET, the AOCP block is enabled and monitors the current through the sensing resistor. The voltage across the resistor is then compared with a preset AOCP level. If the sensing resistor voltage is greater than the AOCP level, the set signal is applied to the latch, resulting in the shutdown of SMPS. This protection is implemented in the latch mode.

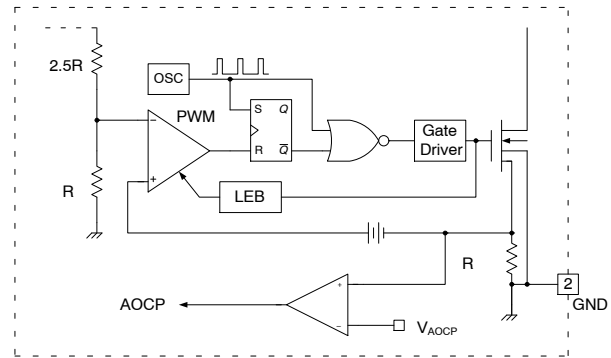


Figure 35. AOCP Block

#### Over-Voltage Protection (OVP)

If the secondary side feedback circuit malfunctions or a solder defect causes an open in the feedback path, the current through the opto-coupler transistor becomes almost zero. Then,  $V_{fb}$  climbs up in a similar manner to the over load situation, forcing the preset maximum current to be supplied to the SMPS until the over load protection triggers. Because more energy than required is provided to the output, the output voltage may exceed the rated voltage before the overload protection triggers, resulting in the breakdown of the devices in the secondary side. In order to prevent this situation, an over voltage protection (OVP) circuit is employed. In general, the peak voltage of the sync signal is proportional to the output voltage and the FSCQ series uses a sync signal instead of directly monitoring the output voltage. If the sync signal exceeds 12 V, an OVP is triggered resulting in a shutdown of SMPS. In order to avoid undesired triggering of OVP during normal operation, the peak voltage of the sync signal should be designed to be below 12 V. This protection is implemented in the auto restart mode.

## Thermal Shutdown (TSD)

The SENSEFET and the control IC are built in one package. This makes it easy for the control IC to detect abnormal over temperature of the SENSEFET. When the temperature exceeds approximately 150°C, the thermal shutdown triggers. This protection is implemented in the latch mode.

## Soft Start

The FSCQ series has an internal soft-start circuit that increases PWM comparator's inverting input voltage together with the SENSEFET current slowly after it starts up. The typical soft start time is 20 ms. The pulse width to the power switching device is progressively increased to establish the correct working conditions for transformers, inductors, and capacitors. Increasing the pulse width to the power switching device also helps prevent transformer saturation and reduces the stress on the secondary diode during startup. For a fast build up of the output voltage, an offset is introduced in the soft-start reference current.

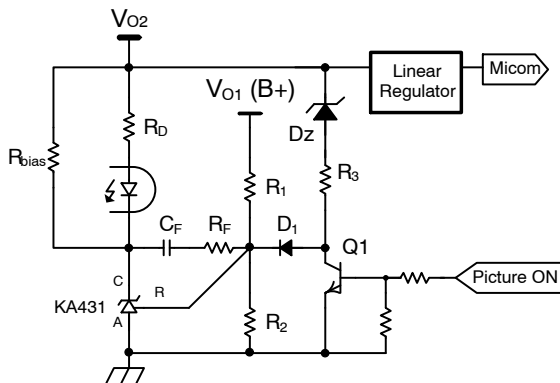
## Burst Operation

To minimize the power consumption in the standby mode, the FSCQ series employs burst operation. Once FSCQ series enters burst mode, FSCQ series allows all output voltages and effective switching frequency to be reduced. Figure 36 shows the typical feedback circuit for C-TV applications. In normal operation, the picture on signal is applied and the transistor Q<sub>1</sub> is turned on, which decouples R<sub>3</sub>, D<sub>Z</sub> and D<sub>1</sub> from the feedback network. Therefore, only V<sub>O1</sub> is regulated by the feedback circuit in normal operation and determined by R<sub>1</sub> and R<sub>2</sub> as:

$$V_{O1}^{NORM} = 2.5 \cdot \left( \frac{R_1 + R_2}{R_2} \right) \quad (\text{eq. 6})$$

In standby mode, the picture ON signal is disabled and the transistor Q<sub>1</sub> is turned off, which couples R<sub>3</sub>, D<sub>Z</sub>, and D<sub>1</sub> to the reference pin of KA431. Then, V<sub>O2</sub> is determined by the Zener diode breakdown voltage. Assuming that the forward voltage drop of D<sub>1</sub> is 0.7 V, V<sub>O2</sub> in standby mode is approximately given by:

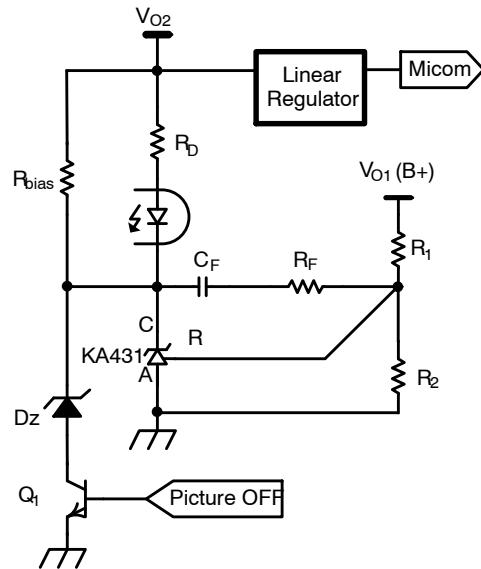
$$V_{O2}^{STBY} = V_Z + 0.7 + 2.5 \quad (\text{eq. 7})$$



**Figure 36. Typical Feedback Circuit to Drop Output Voltage in Standby Mode**

Figure 38 shows the burst mode operation waveforms. When the picture ON signal is disabled, Q<sub>1</sub> is turned off and R<sub>3</sub> and D<sub>Z</sub> are connected to the reference pin of KA431 through D<sub>1</sub>. Before V<sub>O2</sub> drops to V<sub>O2</sub><sup>stby</sup>, the voltage on the reference pin of KA431 is higher than 2.5 V, which increases the current through the opto LED. This pulls down the feedback voltage (V<sub>FB</sub>) of FSCQ series and forces FSCQ series to stop switching. If the switching is disabled longer than 1.4 ms, FSCQ series enters into burst operation and the operating current is reduced from I<sub>OP</sub> to 0.25 mA (I<sub>OB</sub>). Since there is no switching, V<sub>O2</sub> decreases until it reaches V<sub>O2</sub><sup>stby</sup>. As V<sub>O2</sub> reaches V<sub>O2</sub><sup>stby</sup>, the current through the opto LED decreases allowing the feedback voltage to rise. When the feedback voltage reaches 0.4 V, FSCQ series resumes switching with a predetermined peak drain current of 0.9 A. After burst switching for 1.4 ms, FSCQ series stops switching and checks the feedback voltage. If the feedback voltage is below 0.4 V, FSCQ series stops switching until the feedback voltage increases to 0.4 V. If the feedback voltage is above 0.4 V, FSCQ series goes back to the normal operation. The output voltage drop circuit can be implemented alternatively, as shown in Figure 37. In the circuit, the FSCQ series goes into burst mode, when picture off signal is applied to Q<sub>1</sub>. Then, V<sub>O2</sub> is determined by the Zener diode breakdown voltage. Assuming that the forward voltage drop of opto LED is 1 V, the approximate value of V<sub>O2</sub> in standby mode is given by:

$$V_{O2}^{STBY} = V_Z + 1 \quad (\text{eq. 8})$$



**Figure 37. Feedback Circuit to Drop Output Voltage in Standby Mode**

# FSCQ Series

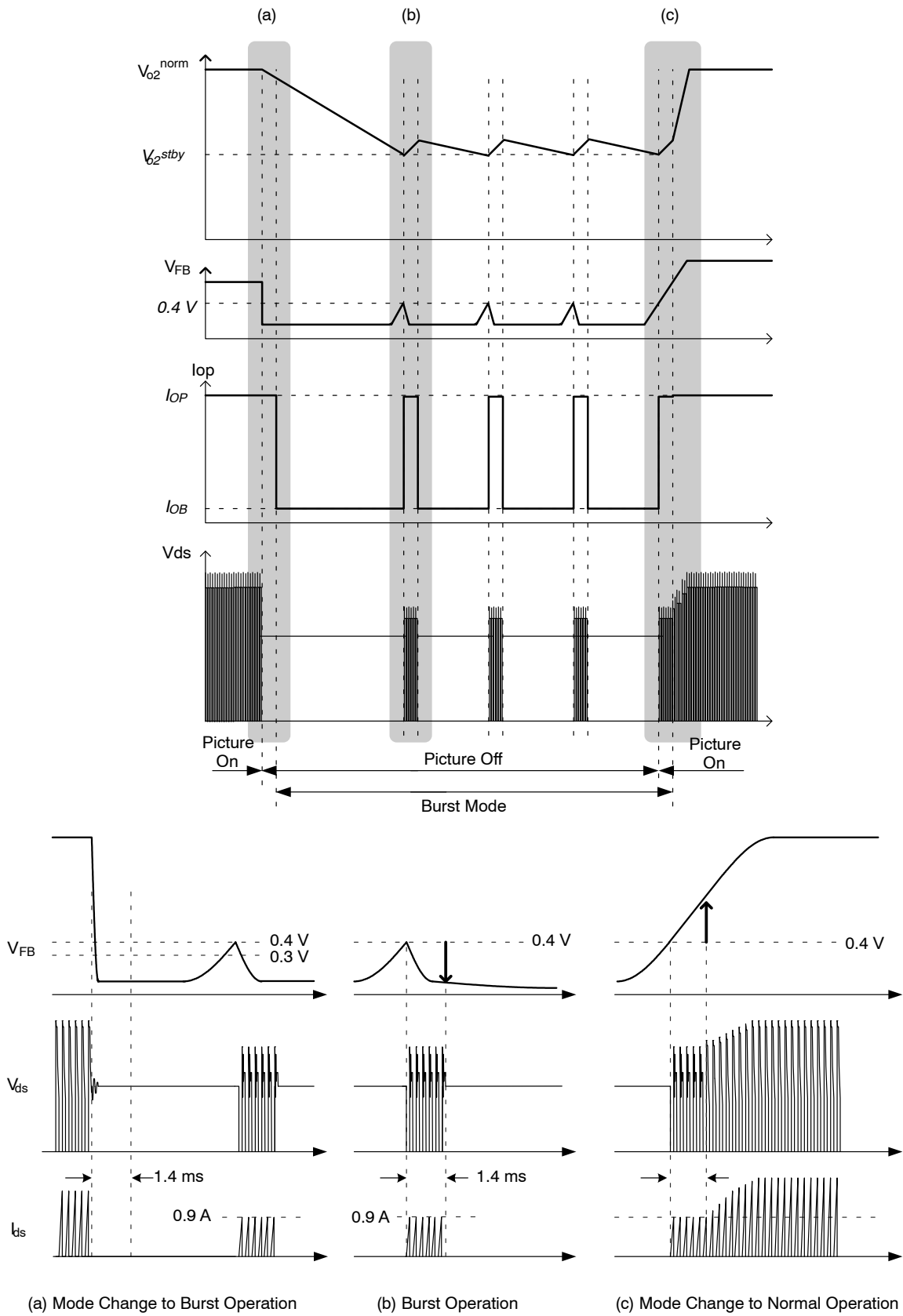


Figure 38. Burst Operation Waveforms

## FSCQ Series

### FSCQ0765RT Typical Application Circuit

#### FSCQ0765RT TYPICAL APPLICATION CIRCUIT

| Application | Output Power | Input Voltage                                | Output Voltage (Max. Current) |
|-------------|--------------|----------------------------------------------|-------------------------------|
| C-TV        | 83 W         | Universal Input<br>(90–270 V <sub>ac</sub> ) | 12 V (1 A)                    |
|             |              |                                              | 18 V (0.5 A)                  |
|             |              |                                              | 125 V (0.4 A)                 |
|             |              |                                              | 24 V (0.5 A)                  |

#### Features

- High Efficiency (>83% at 90 V<sub>ac</sub> Input)
- Wider Load Range through the Extended Quasi-Resonant Operation
- Low Standby Mode Power Consumption (<1 W)
- Low Component Count

- Enhanced System Reliability Through Various Protection Functions
- Internal Soft-Start (20 ms)

#### Key Design Notes

- 24 V Output Designed to Drop to 8 V in Standby Mode

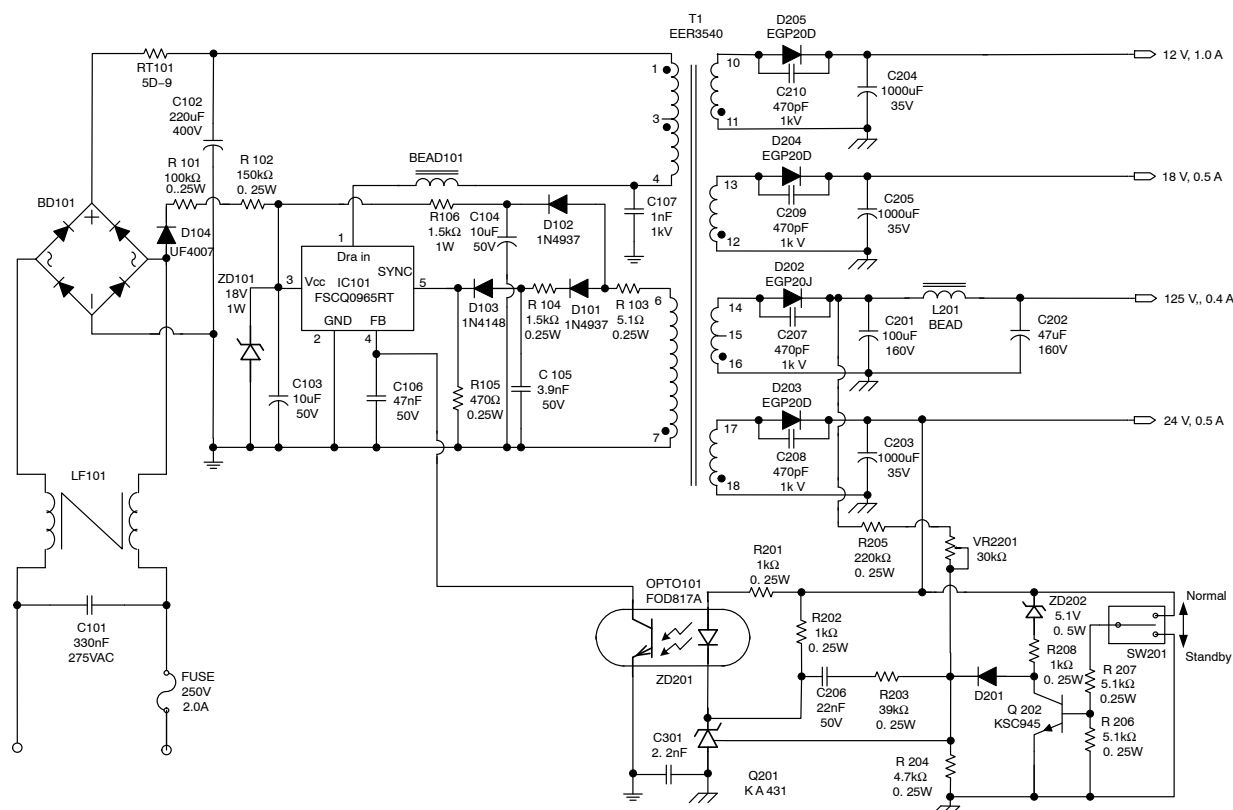


Figure 39. FSCQ0765RT Typical Application Circuit Schematic

## FSCQ Series

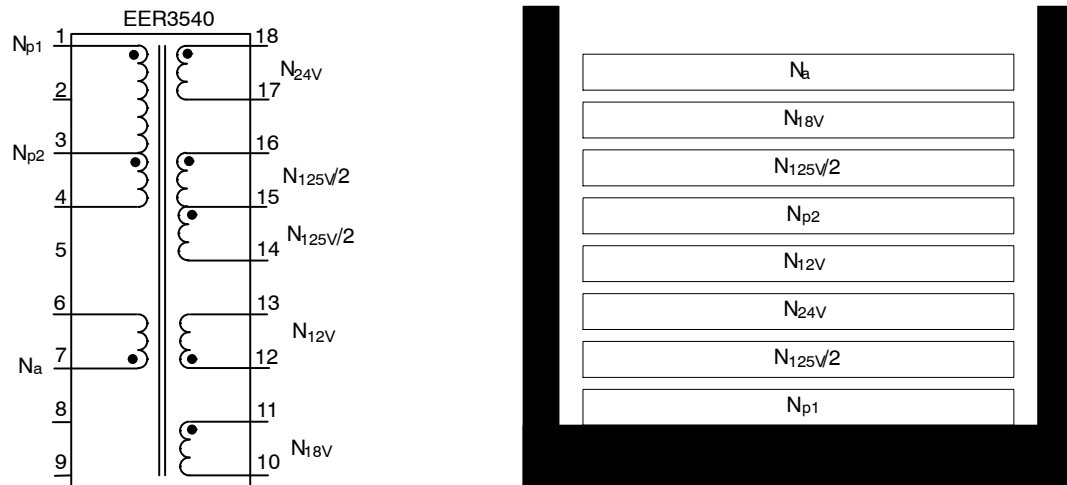


Figure 40. Transformer Schematic Diagram

### WINDING SPECIFICATION

| No                  | Pin (s → f) | Wire     | Turns | Winding Method |
|---------------------|-------------|----------|-------|----------------|
| N <sub>p1</sub>     | 1–3         | 0.5φ x 1 | 32    | Center Winding |
| N <sub>125V/2</sub> | 16–15       | 0.5φ x 1 | 32    |                |
| N <sub>24V</sub>    | 18–17       | 0.4φ x 2 | 13    |                |
| N <sub>12V</sub>    | 12–13       | 0.5φ x 2 | 7     |                |
| N <sub>p2</sub>     | 3–4         | 0.5φ x 1 | 32    |                |
| N <sub>125V/2</sub> | 15–14       | 0.5φ x 1 | 32    |                |
| N <sub>18V</sub>    | 11–10       | 0.4φ x 2 | 10    |                |
| N <sub>a</sub>      | 7–6         | 0.3φ x 1 | 20    |                |

### ELECTRICAL CHARACTERISTICS

|                    | Pin | Specification | Remarks                   |
|--------------------|-----|---------------|---------------------------|
| Inductance         | 1–3 | 515 μH ±5%    | 1 kHz, 1 V                |
| Leakage Inductance | 1–3 | 10 μH Max.    | 2 <sup>nd</sup> all short |

#### Core & Bobbin

- Core: EER3540

- Bobbin: EER3540
- A<sub>e</sub>: 107 mm<sup>2</sup>

## FSCQ Series

### BILL OF MATERIALS

| Part             | Value                        | Note           |
|------------------|------------------------------|----------------|
| <b>Fuse</b>      |                              |                |
| FUSE             | 250 V / 2 A                  |                |
| <b>NTC</b>       |                              |                |
| RT101            | 5D-9                         |                |
| <b>Resistor</b>  |                              |                |
| R101             | 100 k $\Omega$               | 0.25 W         |
| R102             | 150 k $\Omega$               | 0.25 W         |
| R103             | 5.1 $\Omega$                 | 0.25 W         |
| R104             | 1.5 k $\Omega$               | 0.25 W         |
| R105             | 470 $\Omega$                 | 0.25 W         |
| R106             | 1.5 k $\Omega$               | 1 W            |
| R107             | Open                         |                |
| R201             | 1 k $\Omega$                 | 0.25 W         |
| R202             | 1 k $\Omega$                 | 0.25 W         |
| R203             | 39 k $\Omega$                | 0.25 W         |
| R204             | 4.7 k $\Omega$               | 0.25 W, 1%     |
| R205             | 220 k $\Omega$               | 0.25 W, 1%     |
| R206             | 5.1 k $\Omega$               | 0.25 W         |
| R207             | 5.1 k $\Omega$               | 0.25 W         |
| R208             | 1 k $\Omega$                 | 0.25 W         |
| VR201            | 30 k $\Omega$                |                |
| <b>Capacitor</b> |                              |                |
| C101             | 330 nF / 275 V <sub>AC</sub> |                |
| C102             | 220 $\mu$ F / 400 V          | Box Capacitor  |
| C103             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C104             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C105             | 3.9 nF / 50 V                | Electrolytic   |
| C106             | 47 nF / 50 V                 | Film Capacitor |
| C107             | 680 pF / 1 kV                | Film Capacitor |
| C108             | Open                         |                |
| C201             | 100 $\mu$ F / 160 V          | Electrolytic   |
| C202             | 47 $\mu$ F / 160 V           | Electrolytic   |
| C203             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C204             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C205             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C206             | 22 nF / 50 V                 | Film Capacitor |

### BILL OF MATERIALS (continued)

| Part                | Value         | Note                 |
|---------------------|---------------|----------------------|
| C207                | 470 pF / 1 kV | Ceramic Capacitor    |
| C208                | 470 pF / 1 kV | Ceramic Capacitor    |
| C209                | 470 pF / 1 kV | Ceramic Capacitor    |
| C210                | 470 pF / 1 kV | Ceramic Capacitor    |
| C301                | 2.2 nF / 1 kV | AC Ceramic Capacitor |
| <b>Inductor</b>     |               |                      |
| BEAD101             | BEAD          |                      |
| BEAD201             | 5 $\mu$ H     | 3 A                  |
| <b>Diode</b>        |               |                      |
| D101                | 1N4937        | 1 A, 600 V           |
| D102                | 1N4937        | 1 A, 600 V           |
| D103                | 1N4148        | 0.15 A, 50 V         |
| D104                | Short         |                      |
| D105                | Open          |                      |
| ZD101               | 1N4746        | 18 V, 1 W            |
| ZD102               | Open          |                      |
| ZD201               | 1N5231        | 5.1 V, 0.5 W         |
| D201                | 1N4148        | 0.15 A, 50 V         |
| D202                | EGP20J        | 2 A, 600 V           |
| D203                | EGP20D        | 2 A, 200 V           |
| D204                | EGP20D        | 2 A, 200 V           |
| D205                | EGP20D        | 2 A, 200 V           |
| <b>Bridge Diode</b> |               |                      |
| BD101               | GSIB660       | 6 A, 600 V           |
| <b>Line Filter</b>  |               |                      |
| LF101               |               | 14 mH                |
| <b>Transformer</b>  |               |                      |
| T101                | EER3540       |                      |
| <b>Switch</b>       |               |                      |
| SW201               | ON/OFF        | For MCU Signal       |
| <b>IC</b>           |               |                      |
| IC101               | FSCQ0765RT    | TO-220F-5L           |
| OPT101              | FOD817A       |                      |
| Q201                | KA431LZ       | TO-92                |
| Q202                | KSC945        |                      |

## FSCQ Series

### FSCQ0965RT Typical Application Circuit

#### FSCQ0965RT TYPICAL APPLICATION CIRCUIT

| Application | Output Power | Input Voltage                                | Output Voltage (Max. Current) |
|-------------|--------------|----------------------------------------------|-------------------------------|
| C-TV        | 102 W        | Universal Input<br>(90–270 V <sub>ac</sub> ) | 12 V (0.5 A)                  |
|             |              |                                              | 18 V (0.5 A)                  |
|             |              |                                              | 125 V (0.5 A)                 |
|             |              |                                              | 24 V (1.0 A)                  |

#### Features

- High Efficiency (>83% at 90 V<sub>ac</sub> Input)
- Wider Load Range through the Extended Quasi-Resonant Operation
- Low Standby Mode Power Consumption (<1 W)
- Low Component Count

- Enhanced System Reliability Through Various Protection Functions
- Internal Soft-Start (20 ms)

#### Key Design Notes

- 24 V Output Designed to Drop to 8 V in Standby Mode

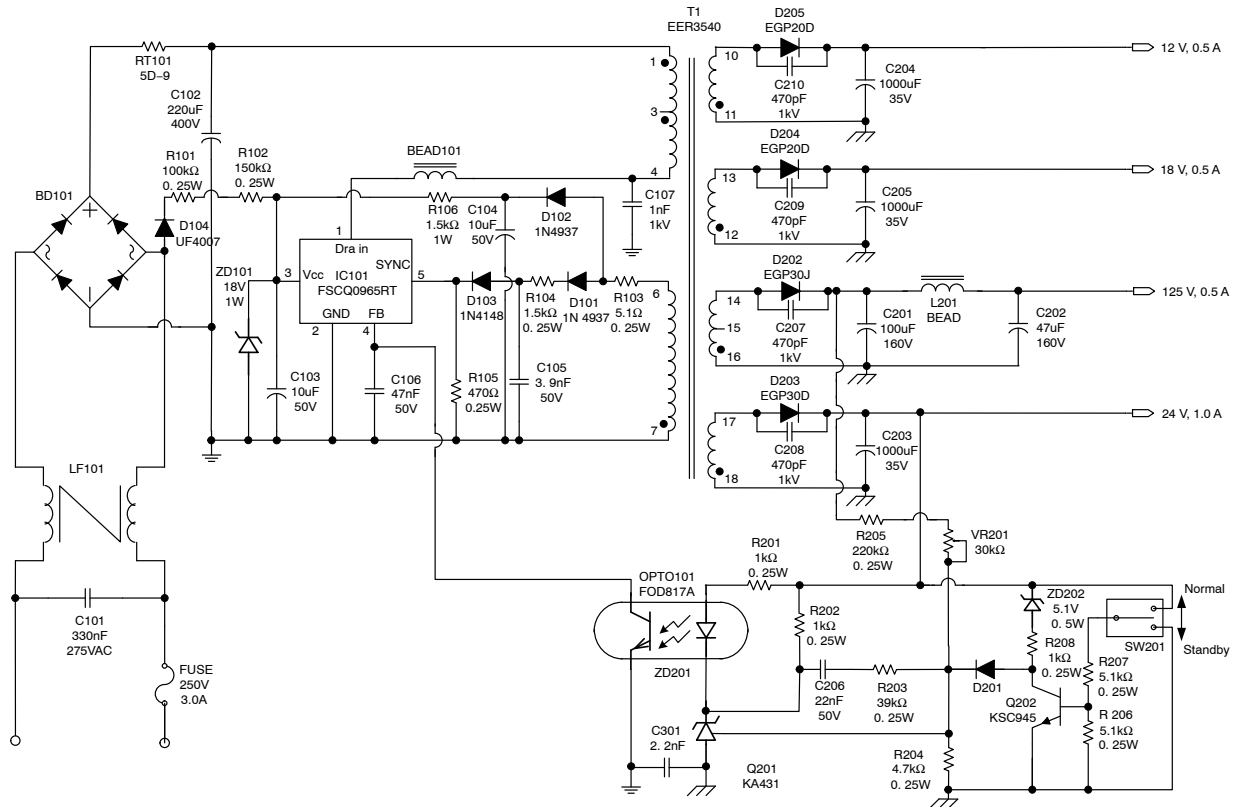


Figure 41. FSCQ0965RT Typical Application Circuit Schematic

## FSCQ Series

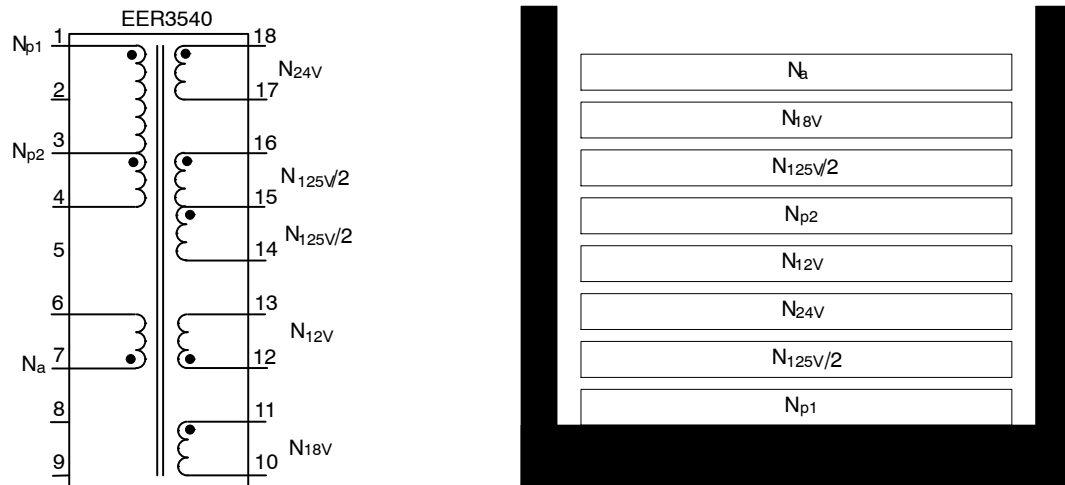


Figure 42. Transformer Schematic Diagram

### WINDING SPECIFICATION

| No                  | Pin (s → f) | Wire     | Turns | Winding Method |
|---------------------|-------------|----------|-------|----------------|
| N <sub>p1</sub>     | 1–3         | 0.5φ x 1 | 32    | Center Winding |
| N <sub>125V/2</sub> | 16–15       | 0.5φ x 1 | 32    |                |
| N <sub>24V</sub>    | 18–17       | 0.4φ x 2 | 13    |                |
| N <sub>12V</sub>    | 12–13       | 0.5φ x 2 | 7     |                |
| N <sub>p2</sub>     | 3–4         | 0.5φ x 1 | 32    |                |
| N <sub>125V/2</sub> | 15–14       | 0.5φ x 1 | 32    |                |
| N <sub>18V</sub>    | 11–10       | 0.4φ x 2 | 10    |                |
| N <sub>a</sub>      | 7–6         | 0.3φ x 1 | 20    |                |

### ELECTRICAL CHARACTERISTICS

|                    | Pin | Specification | Remarks                   |
|--------------------|-----|---------------|---------------------------|
| Inductance         | 1–3 | 410 μH ±5%    | 1 kHz, 1 V                |
| Leakage Inductance | 1–3 | 10 μH Max.    | 2 <sup>nd</sup> all short |

#### Core & Bobbin

- Core: EER3540

- Bobbin: EER3540
- A<sub>e</sub>: 107 mm<sup>2</sup>

## FSCQ Series

### BILL OF MATERIALS

| Part             | Value                        | Note           |
|------------------|------------------------------|----------------|
| <b>Fuse</b>      |                              |                |
| FUSE             | 250 V / 3 A                  |                |
| <b>NTC</b>       |                              |                |
| RT101            | 5D-9                         |                |
| <b>Resistor</b>  |                              |                |
| R101             | 100 k $\Omega$               | 0.25 W         |
| R102             | 150 k $\Omega$               | 0.25 W         |
| R103             | 5.1 $\Omega$                 | 0.25 W         |
| R104             | 1.5 k $\Omega$               | 0.25 W         |
| R105             | 470 $\Omega$                 | 0.25 W         |
| R106             | 1.5 k $\Omega$               | 1 W            |
| R107             | Open                         |                |
| R201             | 1 k $\Omega$                 | 0.25 W         |
| R202             | 1 k $\Omega$                 | 0.25 W         |
| R203             | 39 k $\Omega$                | 0.25 W         |
| R204             | 4.7 k $\Omega$               | 0.25 W, 1%     |
| R205             | 220 k $\Omega$               | 0.25 W, 1%     |
| R206             | 5.1 k $\Omega$               | 0.25 W         |
| R207             | 5.1 k $\Omega$               | 0.25 W         |
| R208             | 1 k $\Omega$                 | 0.25 W         |
| VR201            | 30 k $\Omega$                |                |
| <b>Capacitor</b> |                              |                |
| C101             | 330 nF / 275 V <sub>AC</sub> |                |
| C102             | 220 $\mu$ F / 400 V          | Box Capacitor  |
| C103             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C104             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C105             | 3.9 nF / 50 V                | Electrolytic   |
| C106             | 47 nF / 50 V                 | Film Capacitor |
| C107             | 1 nF / 1 kV                  | Film Capacitor |
| C108             | Open                         |                |
| C201             | 100 $\mu$ F / 160 V          | Electrolytic   |
| C202             | 47 $\mu$ F / 160 V           | Electrolytic   |
| C203             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C204             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C205             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C206             | 22 nF / 50 V                 | Film Capacitor |

### BILL OF MATERIALS (continued)

| Part                | Value         | Note                 |
|---------------------|---------------|----------------------|
| C207                | 470 pF / 1 kV | Ceramic Capacitor    |
| C208                | 470 pF / 1 kV | Ceramic Capacitor    |
| C209                | 470 pF / 1 kV | Ceramic Capacitor    |
| C210                | 470 pF / 1 kV | Ceramic Capacitor    |
| C301                | 2.2 nF / 1 kV | AC Ceramic Capacitor |
| <b>Inductor</b>     |               |                      |
| BEAD101             | BEAD          |                      |
| BEAD201             | 5 $\mu$ H     | 3 A                  |
| <b>Diode</b>        |               |                      |
| D101                | 1N4937        | 1 A, 600 V           |
| D102                | 1N4937        | 1 A, 600 V           |
| D103                | 1N4148        | 0.15 A, 50 V         |
| D104                | Short         |                      |
| D105                | Open          |                      |
| ZD101               | 1N4746        | 18 V, 1 W            |
| ZD102               | Open          |                      |
| ZD201               | 1N5231        | 5.1 V, 0.5 W         |
| D201                | 1N4148        | 0.15 A, 50 V         |
| D202                | EGP30J        | 3 A, 600 V           |
| D203                | EGP30D        | 3 A, 200 V           |
| D204                | EGP20D        | 2 A, 200 V           |
| D205                | EGP20D        | 2 A, 200 V           |
| <b>Bridge Diode</b> |               |                      |
| BD101               | GSIB660       | 6 A, 600 V           |
| <b>Line Filter</b>  |               |                      |
| LF101               |               | 14 mH                |
| <b>Transformer</b>  |               |                      |
| T101                | EER3540       |                      |
| <b>Switch</b>       |               |                      |
| SW201               | ON/OFF        | For MCU Signal       |
| <b>IC</b>           |               |                      |
| IC101               | FSCQ0965RT    | TO-220F-5L           |
| OPT101              | FOD817A       |                      |
| Q201                | KA431LZ       | TO-92                |
| Q202                | KSC945        |                      |

## FSCQ Series

### FSCQ1265RT Typical Application Circuit

#### FSCQ1265RT TYPICAL APPLICATION CIRCUIT

| Application | Output Power | Input Voltage                                | Output Voltage (Max. Current) |
|-------------|--------------|----------------------------------------------|-------------------------------|
| C-TV        | 132 W        | Universal Input<br>(90–270 V <sub>ac</sub> ) | 8.5 V (0.5 A)                 |
|             |              |                                              | 15 V (0.5 A)                  |
|             |              |                                              | 140 V (0.6 A)                 |
|             |              |                                              | 24 V (1.5 A)                  |

#### Features

- High Efficiency (>83% at 90 V<sub>ac</sub> Input)
- Wider Load Range through the Extended Quasi-Resonant Operation
- Low Standby Mode Power Consumption (<1 W)
- Low Component Count

- Enhanced System Reliability Through Various Protection Functions
- Internal Soft-Start (20 ms)

#### Key Design Notes

- 24 V Output Designed to Drop to 8 V in Standby Mode

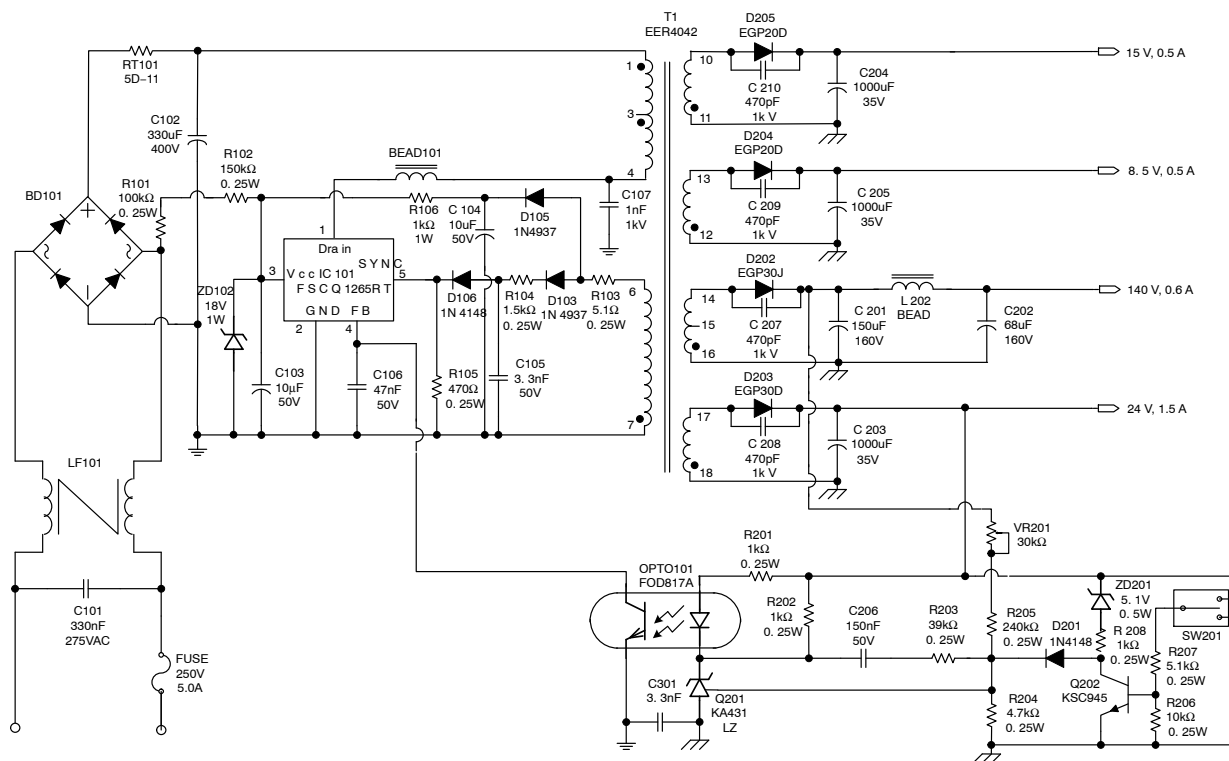


Figure 43. FSCQ1265RT Typical Application Circuit Schematic

## FSCQ Series

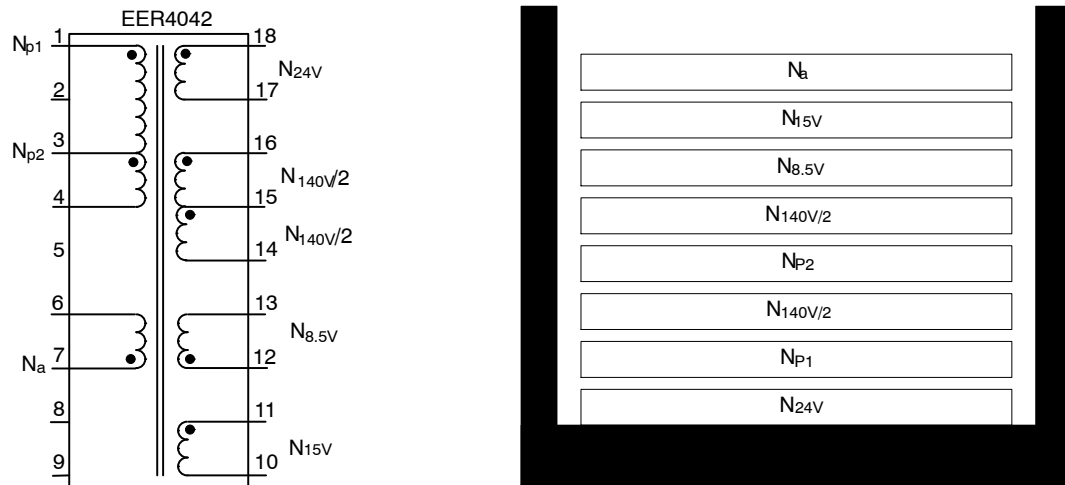


Figure 44. Transformer Schematic Diagram

### WINDING SPECIFICATION

| No                  | Pin (s → f) | Wire          | Turns | Winding Method |
|---------------------|-------------|---------------|-------|----------------|
| N <sub>24</sub>     | 18–17       | 0.65φ × 2     | 8     | Space Winding  |
| N <sub>p1</sub>     | 1–3         | 0.1φ × 10 × 2 | 20    | Center Winding |
| N <sub>140V/2</sub> | 16–15       | 0.1φ × 10 × 2 | 23    | Center Winding |
| N <sub>p2</sub>     | 3–4         | 0.1φ × 10 × 2 | 20    | Center Winding |
| N <sub>140V/2</sub> | 15–14       | 0.1φ × 10 × 2 | 22    | Center Winding |
| N <sub>8.5V</sub>   | 12–13       | 0.6φ × 1      | 3     | Space Winding  |
| N <sub>15V</sub>    | 11–10       | 0.6φ × 1      | 6     | Space Winding  |
| N <sub>a</sub>      | 7–6         | 0.3φ × 1      | 13    | Space Winding  |

### ELECTRICAL CHARACTERISTICS

|                    | Pin | Specification | Remarks                   |
|--------------------|-----|---------------|---------------------------|
| Inductance         | 1–4 | 315 μH ±5%    | 1 kHz, 1 V                |
| Leakage Inductance | 1–4 | 10 μH Max.    | 2 <sup>nd</sup> all short |

#### Core & Bobbin

- Core: EER4042

- Bobbin: EER4042 (18 Pin)
- A<sub>e</sub>: 153 mm<sup>2</sup>

## FSCQ Series

### BILL OF MATERIALS

| Part             | Value                        | Note           |
|------------------|------------------------------|----------------|
| <b>Fuse</b>      |                              |                |
| FUSE             | 250 V / 5 A                  |                |
| <b>NTC</b>       |                              |                |
| RT101            | 5D-11                        |                |
| <b>Resistor</b>  |                              |                |
| R101             | 100 k $\Omega$               | 0.25 W         |
| R102             | 150 k $\Omega$               | 0.25 W         |
| R103             | 5.1 $\Omega$                 | 0.25 W         |
| R104             | 1.5 k $\Omega$               | 0.25 W         |
| R105             | 470 $\Omega$                 | 0.25 W         |
| R106             | 1 k $\Omega$                 | 1 W            |
| R107             | Open                         |                |
| R201             | 1 k $\Omega$                 | 0.25 W         |
| R202             | 1 k $\Omega$                 | 0.25 W         |
| R203             | 39 k $\Omega$                | 0.25 W         |
| R204             | 4.7 k $\Omega$               | 0.25 W, 1%     |
| R205             | 240 k $\Omega$               | 0.25 W, 1%     |
| R206             | 10 k $\Omega$                | 0.25 W         |
| R207             | 5.1 k $\Omega$               | 0.25 W         |
| R208             | 1 k $\Omega$                 | 0.25 W         |
| VR201            | 30 k $\Omega$                |                |
| <b>Capacitor</b> |                              |                |
| C101             | 330 nF / 275 V <sub>AC</sub> |                |
| C102             | 330 $\mu$ F / 400 V          | Box Capacitor  |
| C103             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C104             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C105             | 3.3 nF / 50 V                | Electrolytic   |
| C106             | 47 nF / 50 V                 | Film Capacitor |
| C107             | 1 nF / 1 kV                  | Film Capacitor |
| C108             | Open                         |                |
| C201             | 100 $\mu$ F / 160 V          | Electrolytic   |
| C202             | 68 $\mu$ F / 160 V           | Electrolytic   |
| C203             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C204             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C205             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C206             | 150 nF / 50 V                | Film Capacitor |

### BILL OF MATERIALS (continued)

| Part                | Value         | Note                 |
|---------------------|---------------|----------------------|
| C207                | 470 pF / 1 kV | Ceramic Capacitor    |
| C208                | 470 pF / 1 kV | Ceramic Capacitor    |
| C209                | 470 pF / 1 kV | Ceramic Capacitor    |
| C210                | 470 pF / 1 kV | Ceramic Capacitor    |
| C301                | 3.3 nF / 1 kV | AC Ceramic Capacitor |
| <b>Inductor</b>     |               |                      |
| BEAD101             | BEAD          |                      |
| BEAD201             | 5 $\mu$ H     | 3 A                  |
| <b>Diode</b>        |               |                      |
| D101                | 1N4937        | 1 A, 600 V           |
| D102                | 1N4937        | 1 A, 600 V           |
| D103                | 1N4148        | 0.15 A, 50 V         |
| D104                | Short         |                      |
| D105                | Open          |                      |
| ZD101               | 1N4746        | 18 V, 1 W            |
| ZD102               | Open          |                      |
| ZD201               | 1N5231        | 5.1 V, 0.5 W         |
| D201                | 1N4148        | 0.15 A, 50 V         |
| D202                | EGP30J        | 3 A, 600 V           |
| D203                | EGP30D        | 3 A, 200 V           |
| D204                | EGP20D        | 2 A, 200 V           |
| D205                | EGP20D        | 2 A, 200 V           |
| <b>Bridge Diode</b> |               |                      |
| BD101               | GSIB660       | 6 A, 600 V           |
| <b>Line Filter</b>  |               |                      |
| LF101               |               | 14 mH                |
| <b>Transformer</b>  |               |                      |
| T101                | EER4042       |                      |
| <b>Switch</b>       |               |                      |
| SW201               | ON/OFF        | For MCU Signal       |
| <b>IC</b>           |               |                      |
| IC101               | FSCQ1265RT    | TO-220F-5L           |
| OPT101              | FOD817A       |                      |
| Q201                | KA431LZ       | TO-92                |
| Q202                | KSC945        |                      |

## FSCQ Series

### FSCQ1565RT Typical Application Circuit

### FSCQ1565RT TYPICAL APPLICATION CIRCUIT

| Application | Output Power | Input Voltage                                | Output Voltage (Max. Current) |
|-------------|--------------|----------------------------------------------|-------------------------------|
| C-TV        | 160 W        | Universal Input<br>(90–270 V <sub>ac</sub> ) | 8.5 V (0.5 A)                 |
|             |              |                                              | 15 V (0.5 A)                  |
|             |              |                                              | 140 V (0.8 A)                 |
|             |              |                                              | 24 V (1.5 A)                  |

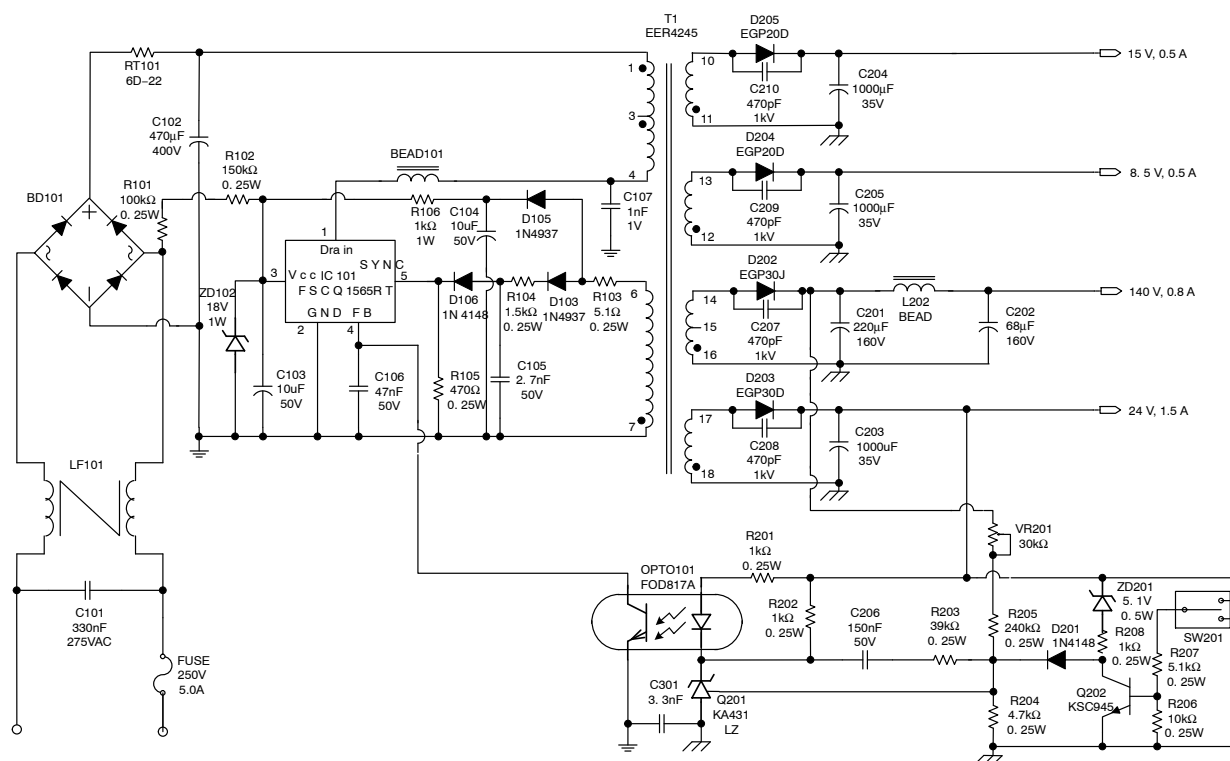
## Features

- High Efficiency (>83% at 90 V<sub>ac</sub> Input)
- Wider Load Range through the Extended Quasi-Resonant Operation
- Low Standby Mode Power Consumption (<1 W)
- Low Component Count

- Enhanced System Reliability Through Various Protection Functions
- Internal Soft-Start (20 ms)

### Key Design Notes

- 24 V Output Designed to Drop to 8 V in Standby Mode



### Figure 45. FSCQ1565RT Typical Application Circuit Schematic

## FSCQ Series

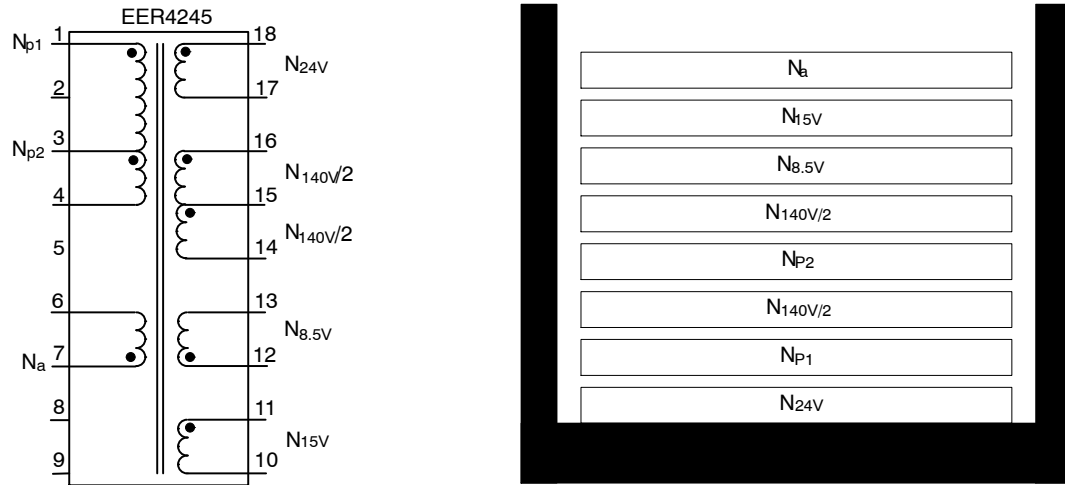


Figure 46. Transformer Schematic Diagram

### WINDING SPECIFICATION

| No                  | Pin (s → f) | Wire           | Turns | Winding Method |
|---------------------|-------------|----------------|-------|----------------|
| N <sub>24V</sub>    | 18–17       | 0.65φ × 2      | 5     | Space Winding  |
| N <sub>p1</sub>     | 1–3         | 0.08φ × 20 × 2 | 13    | Center Winding |
| N <sub>140V/2</sub> | 16–15       | 0.08φ × 20 × 2 | 15    | Center Winding |
| N <sub>p2</sub>     | 3–4         | 0.08φ × 20 × 2 | 13    | Center Winding |
| N <sub>140V/2</sub> | 15–14       | 0.08φ × 20 × 2 | 14    | Center Winding |
| N <sub>8.5V</sub>   | 12–13       | 0.6φ × 1       | 2     | Space Winding  |
| N <sub>15V</sub>    | 11–10       | 0.6φ × 1       | 3     | Space Winding  |
| N <sub>a</sub>      | 7–6         | 0.3φ × 1       | 8     | Space Winding  |

### ELECTRICAL CHARACTERISTICS

|                    | Pin | Specification | Remarks                   |
|--------------------|-----|---------------|---------------------------|
| Inductance         | 1–4 | 220 μH ±5%    | 1 kHz, 1 V                |
| Leakage Inductance | 1–4 | 10 μH Max.    | 2 <sup>nd</sup> all short |

#### Core & Bobbin

- Core: EER4245

- Bobbin: EER4245 (18 Pin)
- A<sub>e</sub>: 201.8 mm<sup>2</sup>

## FSCQ Series

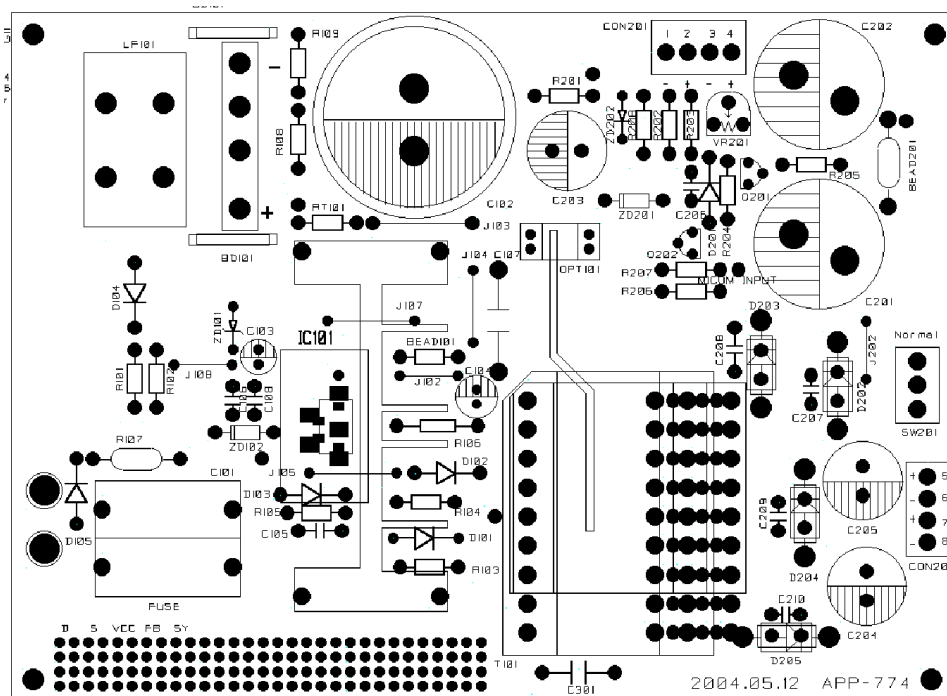
### BILL OF MATERIALS

| Part             | Value                        | Note           |
|------------------|------------------------------|----------------|
| <b>Fuse</b>      |                              |                |
| FUSE             | 250 V / 5 A                  |                |
| <b>NTC</b>       |                              |                |
| RT101            | 6D-22                        |                |
| <b>Resistor</b>  |                              |                |
| R101             | 100 k $\Omega$               | 0.25 W         |
| R102             | 150 k $\Omega$               | 0.25 W         |
| R103             | 5.1 $\Omega$                 | 0.25 W         |
| R104             | 1.5 k $\Omega$               | 0.25 W         |
| R105             | 470 $\Omega$                 | 0.25 W         |
| R106             | 1.5 k $\Omega$               | 1 W            |
| R107             | Open                         |                |
| R201             | 1 k $\Omega$                 | 0.25 W         |
| R202             | 1 k $\Omega$                 | 0.25 W         |
| R203             | 39 k $\Omega$                | 0.25 W         |
| R204             | 4.7 k $\Omega$               | 0.25 W, 1%     |
| R205             | 240 k $\Omega$               | 0.25 W, 1%     |
| R206             | 10 k $\Omega$                | 0.25 W         |
| R207             | 5.1 k $\Omega$               | 0.25 W         |
| R208             | 1 k $\Omega$                 | 0.25 W         |
| VR201            | 30 k $\Omega$                |                |
| <b>Capacitor</b> |                              |                |
| C101             | 330 nF / 275 V <sub>AC</sub> |                |
| C102             | 470 $\mu$ F / 400 V          | Box Capacitor  |
| C103             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C104             | 10 $\mu$ F / 50 V            | Electrolytic   |
| C105             | 2.7 nF / 50 V                | Electrolytic   |
| C106             | 47 nF / 50 V                 | Film Capacitor |
| C107             | 1 nF / 1 kV                  | Film Capacitor |
| C108             | Open                         |                |
| C201             | 220 $\mu$ F / 160 V          | Electrolytic   |
| C202             | 68 $\mu$ F / 160 V           | Electrolytic   |
| C203             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C204             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C205             | 1000 $\mu$ F / 35 V          | Electrolytic   |
| C206             | 150 nF / 50 V                | Film Capacitor |

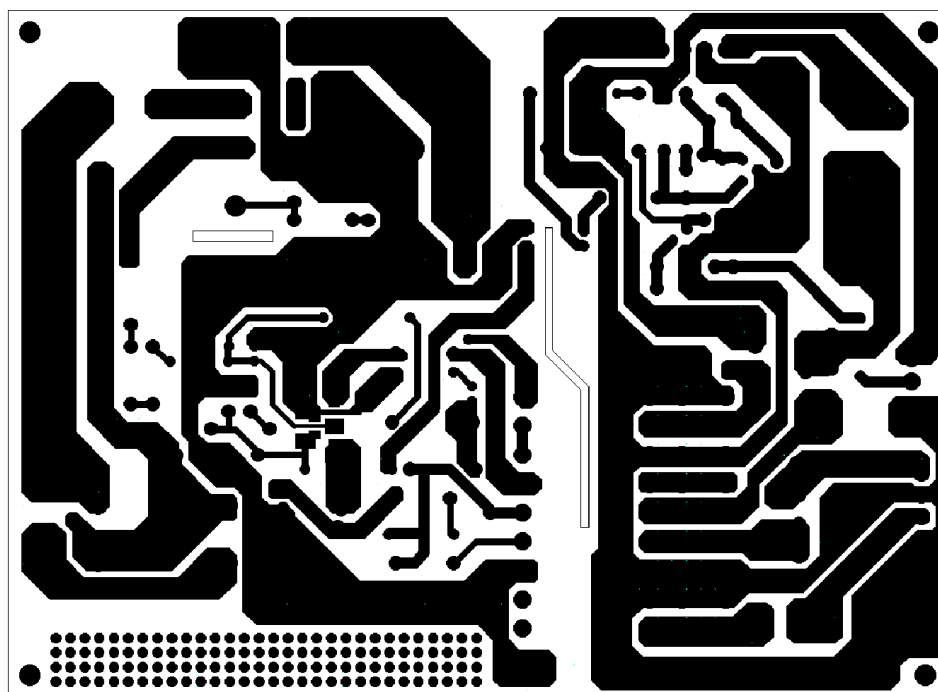
### BILL OF MATERIALS (continued)

| Part                | Value         | Note                 |
|---------------------|---------------|----------------------|
| C207                | 470 pF / 1 kV | Ceramic Capacitor    |
| C208                | 470 pF / 1 kV | Ceramic Capacitor    |
| C209                | 470 pF / 1 kV | Ceramic Capacitor    |
| C210                | 470 pF / 1 kV | Ceramic Capacitor    |
| C301                | 3.3 nF / 1 kV | AC Ceramic Capacitor |
| <b>Inductor</b>     |               |                      |
| BEAD101             | BEAD          |                      |
| BEAD201             | 5 $\mu$ H     | 3 A                  |
| <b>Diode</b>        |               |                      |
| D101                | 1N4937        | 1 A, 600 V           |
| D102                | 1N4937        | 1 A, 600 V           |
| D103                | 1N4148        | 0.15 A, 50 V         |
| D104                | Short         |                      |
| D105                | Open          |                      |
| ZD101               | 1N4746        | 18 V, 1 W            |
| ZD102               | Open          |                      |
| ZD201               | 1N5231        | 5.1 V, 0.5 W         |
| D201                | 1N4148        | 0.15 A, 50 V         |
| D202                | EGP30J        | 3 A, 600 V           |
| D203                | EGP30D        | 3 A, 200 V           |
| D204                | EGP20D        | 2 A, 200 V           |
| D205                | EGP20D        | 2 A, 200 V           |
| <b>Bridge Diode</b> |               |                      |
| BD101               | GSIB660       | 6 A, 600 V           |
| <b>Line Filter</b>  |               |                      |
| LF101               |               | 14 mH                |
| <b>Transformer</b>  |               |                      |
| T101                | EER4245       |                      |
| <b>Switch</b>       |               |                      |
| SW201               | ON/OFF        | For MCU Signal       |
| <b>IC</b>           |               |                      |
| IC101               | FSCQ1565RT    | TO-220F-5L           |
| OPT101              | FOD817A       |                      |
| Q201                | KA431LZ       | TO-92                |
| Q202                | KSC945        |                      |

## PCB Layout



### Figure 47. Top View



### Figure 48. Bottom View

## FSCQ Series

ORDERING INFORMATION TABLE

| Part Number    | Package              | Marking Code | BV <sub>DSS</sub> (V) | R <sub>DS(on)</sub> Max. (Ω) |
|----------------|----------------------|--------------|-----------------------|------------------------------|
| FSCQ0765RTYDTU | TO-220F-5L (Forming) | CQ0765RT     | 650                   | 1.6                          |
| FSCQ0965RTYDTU |                      | CQ0965RT     |                       | 1.2                          |
| FSCQ1265RTYDTU |                      | CQ1265RT     |                       | 0.9                          |
| FSCQ1565RTYDTU |                      | CQ1565RT     |                       | 0.7                          |

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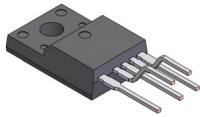
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# MECHANICAL CASE OUTLINE

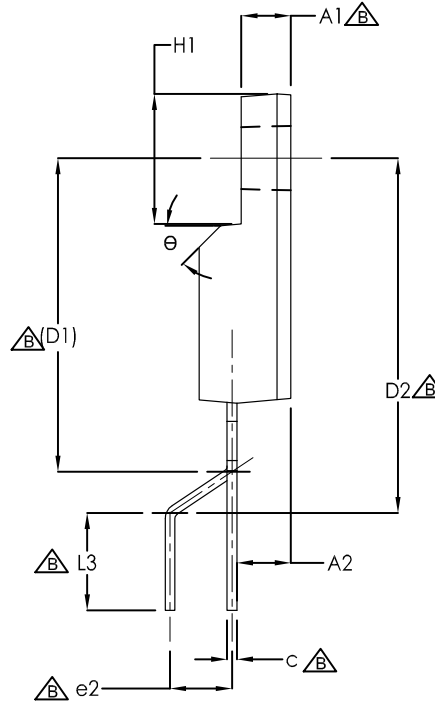
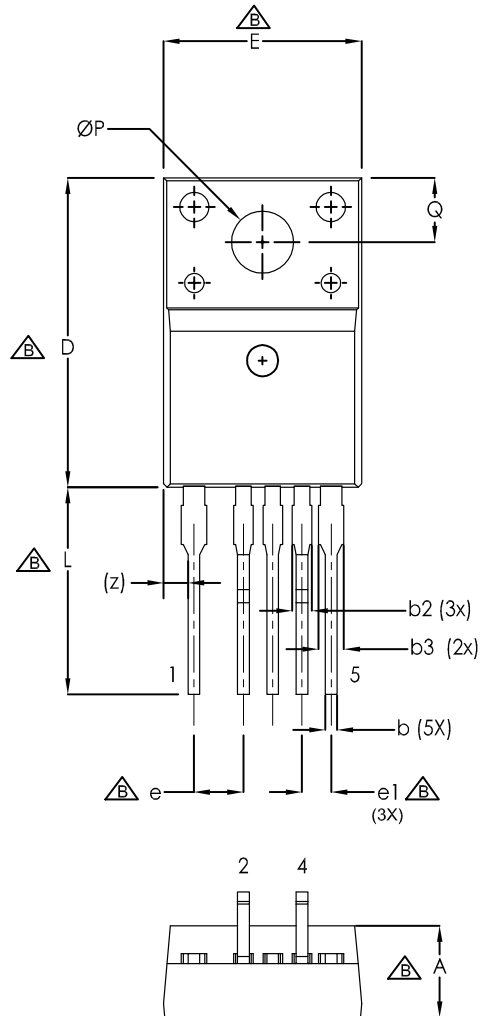
## PACKAGE DIMENSIONS

ON Semiconductor®



**TO-220- FULLPAK 5LD LF**  
CASE 340BH  
ISSUE A

DATE 22 JUL 2021



| DIM   | MILLIMETERS |       |       |
|-------|-------------|-------|-------|
|       | MIN.        | NOM.  | MAX.  |
| A     | 4.50        | 4.70  | 4.90  |
| A1    | 2.34        | 2.54  | 2.74  |
| A2    | 2.56        | 2.76  | 2.96  |
| b     | 0.50        | 0.60  | 0.70  |
| b2    | --          | --    | 1.00  |
| b3    | --          | --    | 1.30  |
| c     | 0.45        | 0.53  | 0.60  |
| D     | 15.67       | 15.87 | 16.07 |
| D1    | 16.08 REF   |       |       |
| D2    | 17.70       | 18.20 | 18.70 |
| E     | 9.96        | 10.16 | 10.36 |
| e     | 2.54 BSC    |       |       |
| e1    | 1.50 BSC    |       |       |
| e2    | 2.88        | 3.18  | 3.48  |
| H1    | 6.48        | 6.68  | 6.88  |
| L     | 10.13       | 10.63 | 11.13 |
| L3    | 4.50        | 5.00  | 5.50  |
| P     | 3.08        | 3.18  | 3.28  |
| Q     | 3.20        | 3.30  | 3.40  |
| z     | 1.50 BSC    |       |       |
| theta | --          | --    | 45°   |

### NOTES:

- EXCEPT WHERE NOTED CONFORMS TO EIAJ SC91A.
- DOES NOT COMPLY EIAJ STD. VALUE.
- ALL DIMENSIONS ARE IN MILLIMETERS.
- DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR PROTRUSIONS.
- DIMENSION AND TOLERANCE AS PER ASME Y14.5-1994.
- DRAWING FILE NAME: TO220C05REV2

|                         |                              |                                                                                                                                                                                     |
|-------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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| <b>DESCRIPTION:</b>     | <b>TO-220 FULLPAK 5LD LF</b> | <b>PAGE 1 OF 1</b>                                                                                                                                                                  |

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